G.E.C. Journal

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SIR HUGO HIRST, Bart.,
Chairman and Managing Director of The General Electric Co., Ltd., who celebrated his 70th birthday on the 26th November, 1933.

G.E.C. Journal

VOL. V. FEBRUARY, 1934. No. 1.

Foreword.

By SIR HUGO HIRST, Bart.
Chairman and Managing Director of The General Electric Co., Ltd.

WHENEVER a new issue of the *G.E.C. Journal* is placed before me, I experience a thrill of pleasure, for in its pages are recorded the scientific and technical achievements of our Company.

In its early days, nearly half a century ago, the G.E.C. was not a powerful force. At that time the handicap of limited financial resources, coupled with a lack of experience, precluded immediate possibility of leadership; we had to follow in the wake of those great companies in other parts of the world, already well-established, who were the first pioneers of organised electrical research and technology.

But the desire to attain a foremost position in the ranks of electrical progress was ever present, and, as we gained strength, plans to this end took shape.

The story of the inception and growth of the Wembley Research Laboratories has often been related. They were provided with the best scientific equipment which could be procured, and to-day, some three hundred workers, led by a group of distinguished scientists, are continually engaged in new fields of investigation. To this central organisation are allied the works development departments, which form so valuable a link between research and workshop practice. At every manufacturing centre of the G.E.C. trained experts are employed in devising methods for the solution of those problems which are inseparably linked with the adaption of proved scientific principles to commercial production.

Moreover, the closest liaison is maintained between the various sections of our technical organisation. At frequent committees, members of the research and development staffs meet those responsible for design and manufacture, for it is only by the free interchange of opinion and idea that our engineers are enabled to utilise to best advantage that technical knowledge and experience which is being steadily accumulated.

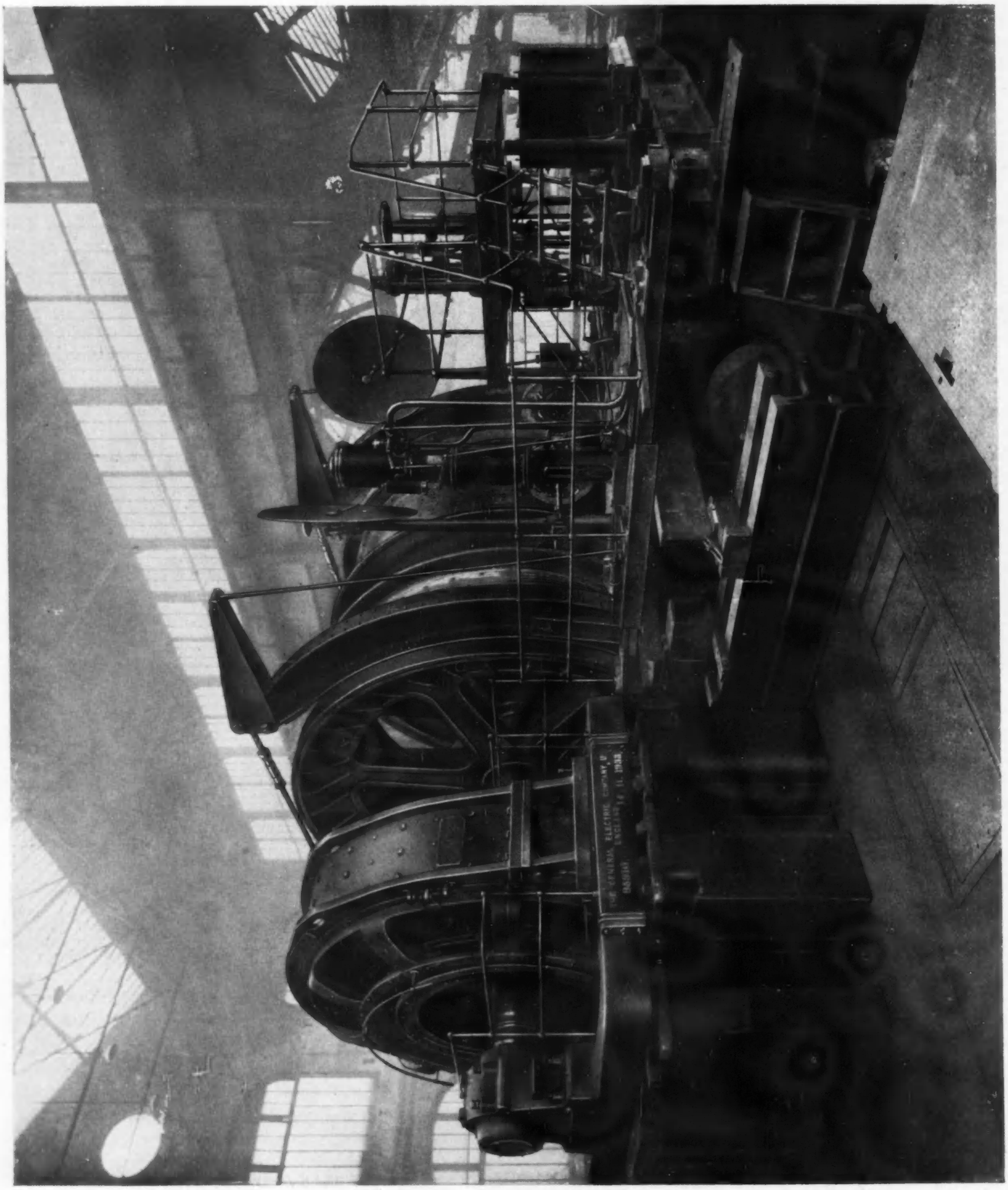
It has never been a part of my belief that records of such progress as we might achieve should be retained within the confines of our organisation. On the contrary, I have always formulated the policy that it was alike a duty and a pleasure to place at the disposal of those who were interested, the results of our experimental work and the methods employed to achieve the successful operation of plant and equipment which we have been permitted to manufacture for installations in every part of the world.

It was in furtherance of this policy that nearly four years ago we decided to inaugurate the *G.E.C. Journal*, and I venture to claim that the information contained in the volumes already completed affords a measure of the fulfilment of the hopes which we entertained when embarking upon the creation of scientific and technical departments which should prove worthy of a company possessing the largest electrical manufacturing resources in the British Empire.

As I glance through the articles which have already been published it is a source of the greatest encouragement to realise the many different directions in which substantial progress has been made even within so short a span of time. The development of the "Osira" lamp and the "Catkin" valve, the introduction of new forms of electric furnaces, the design of marine electric propulsion equipment, the problems associated with steam turbines, the wonders of gas-filled relays; these are but a few of the subjects which have been elucidated faithfully in the pages of the Journal by specialist members of the company's staff.

It is my confident belief that future contributions will continue to breathe the spirit of determination to extend to the farthest possible limits our knowledge of electricity and its manifold applications.

Finally, I trust that readers of this Journal will not fail to avail themselves of the services of any part of our organisation, should they deem that we can furnish them with help or information in electrical matters. It is our earnest desire that there should be frequent contact between ourselves and our friends in all questions of common interest, for it is only by the fullest measure of collaboration that both we and they can play a successful part in that reconstruction and rejuvenation of industry which will enable us to face world competition.



G.E.C. ELECTRIC WINDER FOR THE CHAMPION REEF GOLD MINE, SOUTH INDIA.
A 1,200 h.p. 500 volt 37.5 r.p.m. D.C. motor coupled to a Fraser & Chalmers winder on the test bed at Fraser & Chalmers Engineering Works, Erith, Kent.

Electrical Progress and Development During 1933.

By H. W. RICHARDSON, B.Sc., M.I.E.E.
Editor of the G.E.C. Journal.

THE year 1933 is noteworthy from the electrical point of view, in that its passage has witnessed the introduction of commercial apparatus and equipment which represent the fulfilment of continuous research and experiment in the years immediately preceding.

The most prominent examples of new electrical appliances which bear out this statement are furnished, first, by the "Osira" lamp for street lighting, and secondly, by the "Catkin" receiving valve. Both these important developments were described in articles in the last issue of the *G.E.C. Journal* (Vol. IV, No. 4, Nov, 1933), so that here no more than passing reference is necessary. The "Chance" sand flotation system of cleaning coal also formed the subject of an article in the last issue of the *G.E.C. Journal,* and the information there presented shows the success which has been attained by the system in practical colliery working.

Fig. 1.—Testing radio sets at the G.E.C. Telephone Works by means of modulated radio-frequency oscillators.

A further outstanding event of the year has been the completion of the electrical equipment for the first British Diesel-electrically propelled tug, the *Acklam Cross,* which is fitted with electrical starting equipment. A full description of the plant upon this vessel is given on page 55.

Other matters of electrical interest which have engaged considerable attention during the year relate to colliery equipment, supervisory control gear, the control of electric lifts, oil-filled cable, high frequency measurements, colour floodlighting, and indirectly heated cathode wireless valves. This list might well be prolonged, but other subjects in which progress has been made will find their place at a later stage in this article.

Much important development work was carried out in the Wembley Research Laboratories leading to the commercial successes achieved by "Osira" lamps and "Catkin" valves which have already been mentioned; considerable attention was also given to the design of fittings which would utilise to the utmost advantage the characteristics of the "Osira" lamp. In addition valuable research was undertaken in many other directions, the results of which are reflected in the paragraphs which follow.

RADIO SETS.

There have recently been rapid advances in radio set design, many of these having been incorporated in the sets produced in the autumn of 1933. Thus the main sets are of the superheterodyne type, which has proved capable of providing the high degree of selectivity and sensitivity to meet modern requirements. In this connection circuit design has advanced to allow of one valve behaving both as a first detector valve and oscillator instead of two valves being used as in previous designs; special circuits are used to reduce to a negligible value any heterodyne whistles. The eight valve set illustrates other advances in technique in that detector distortion is removed by the use of a diode detector, and automatic volume control is obtained by the use of another diode. This set also has an automatic device, which enables only the stations really clear of interfering background to be received when desired.

In the battery sets, moving coil loud-speakers are now used, and greatly improved quality results. The 6-valve battery set is also a highly sensitive and selective superheterodyne set, which incorporates the new B.21 output valve. The use of this valve has enabled the user of battery sets to obtain outputs previously available only in mains sets, without an excessive drain on the high tension battery.

These advances in design, involving complicated circuits and increasing output of the sets, have made

even more important the necessity for being in a position to test and adjust rapidly and accurately all the components of the set and also the complete set. For this reason the testing equipment at Coventry Works has been greatly extended. After all the component parts have been tested and adjusted, measurements are made on the overall performance of the set by means of signals which accurately duplicate those which would be produced in the set by broadcasting

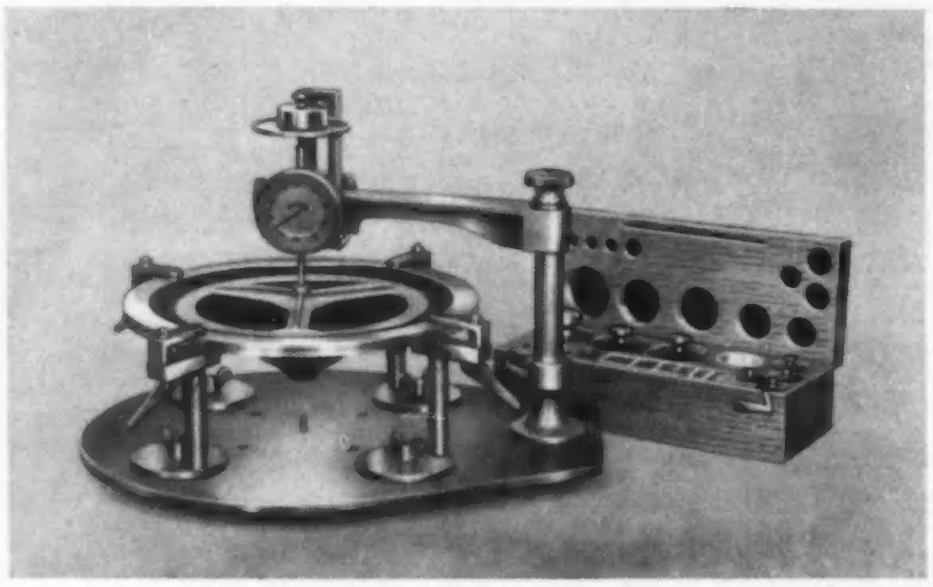


Fig. 2.—An instrument designed to test the stiffness of loud-speaker cones.

stations. To enable this to be accomplished, a modulated radio-frequency oscillator was developed at the Research Laboratories, and several of these are now installed at the works. Five of these oscillators are used to give complete performance tests. They are crystal controlled, and may be modulated with different audio-frequencies so that the operator can know which station, or signal, is being received. The output from these oscillators is distributed to the test positions in concentric copper leads, every test position having an output from each oscillator at which a known radio-frequency voltage is produced. This arrangement is indicated in fig. 1. The signals are applied to the set, which can then be accurately gauged, generally at two points on each waveband. The output-watts developed in the loud-speaker are measured, and for a given input voltage the output must be between fixed limits. Two other oscillators are used to adjust the intermediate frequency filters on the super-heterodyne sets to ensure constant selectivity from set to set.

The use of this apparatus has so accelerated testing and so much improved the uniformity of the product, that it is now being extended to still more critical tests upon set performance.

THE DESIGN OF LOUD-SPEAKERS.

Coincident with the improvement in sets, there has been considerable progress in the design of moving coil loud-speakers giving improved range of frequency reproduction, sensitivity and reliability with vastly simplified construction. With the development of a new technique, several possibilities have been opened up. Outstanding among these has been the closer matching between the set and loud-speaker, resulting in the design of loud-speakers specially suited to individual sets, with consequent great improvement in overall performance. One line of advance has been in the direction of reducing the undesired mechanical impedances of the vibrating systems in such a way that the radiation resistance has become a larger proportion of the whole impedance. This results in increased overall sound output for a given maximum electrical power input, consistent with a given measure of distortion.

Consideration of battery operated receivers has necessitated continuous attention to the problems of economic permanent magnet design. One step on the technical side has been the origination of the one-piece loop type casting in magnet steel, to which a simple mild steel centre-pole only has to be added. This design saves machining costs and reduces magnetic leakage.

Statistical methods have been applied to the control of mass-produced loud-speakers, and in addition, improved and new test methods have made

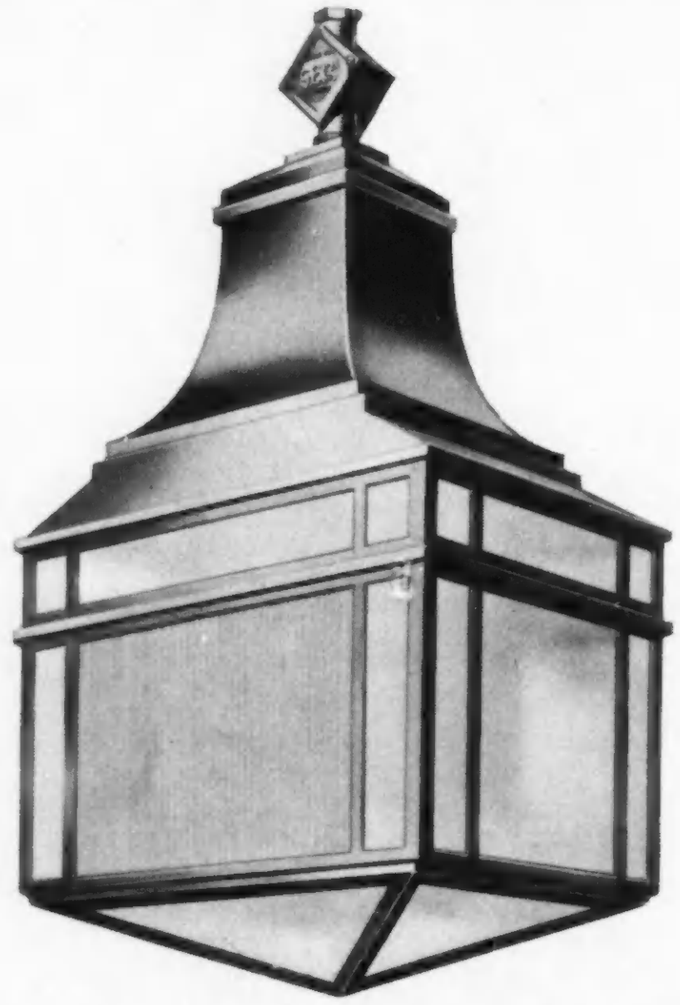


Fig. 3.—The Lewisham lantern for use with the new "Osira" lamps.

it possible and advantageous to test every permanent magnet and every individual cone before assembly, in addition to the usual testing of the finished speaker.

The seamless moulded cones are tested for stiffness of the corrugation, as this mechanical constant largely determines the lower cut-off frequency of the loud-speaker. An instrument designed in the Research Laboratories to measure

this quantity is illustrated in fig. 2. While intended primarily for use in the laboratory it was found, when it was tried out in the Factory, that a girl could test with ease over 600 cones per day, and several of the instruments are now in regular use.

VALVES.

In addition to the development of the "Catkin" valves, work on new materials suitable for valve manufacture has been actively pursued, and in particular a more efficient cathode has been developed. This operates at a lower temperature, and thereby leads to an increased efficiency in the valve as well as a greater factor of safety during life.

PHOTOELECTRIC CELLS.

For some years past there have been few changes in the types and methods of manufacture of commercial types of photoelectric cells. Recently, however, there has been a tendency for users to demand cells of the smallest dimensions possible, especially for use in home talkie and theatre talkie outfits.

It was then found that the existing methods of producing cathodes of the complex caesium oxide structure could not be applied with any great success to these small cells, but a technique has now been devised which yields results for the small cells quite comparable with those obtained for the larger cells.

COLD CATHODE DISCHARGE TUBES.

Developments in cold cathode discharge tubes have consisted chiefly in improvements of existing

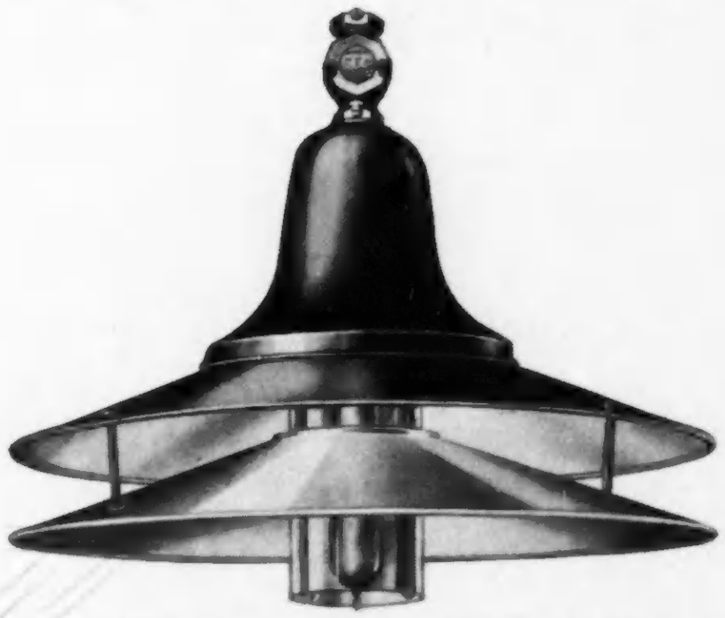


Fig. 4.—The Rochdale lantern designed to give special light distribution having a sharp cut-off when used with the new "Osira" lamps.

types. Thus, for example, it is now possible to use electrodes a fraction of the size found necessary a year or so ago, while still maintaining the same life and efficiency. There has been an increasing demand for high intensity signs for use during the day. This has largely been met by improvements in electrodes. The development of a jade green glass has added an interesting new colour to the large range already existing.

A simple and effective method of tinting the letters of the well known Cleon sign has been developed. In this, the edges of the plate (and not the actual lettering) are coloured with suitable transparent lacquers. The light from the tube passing through the lacquers tints the adjacent

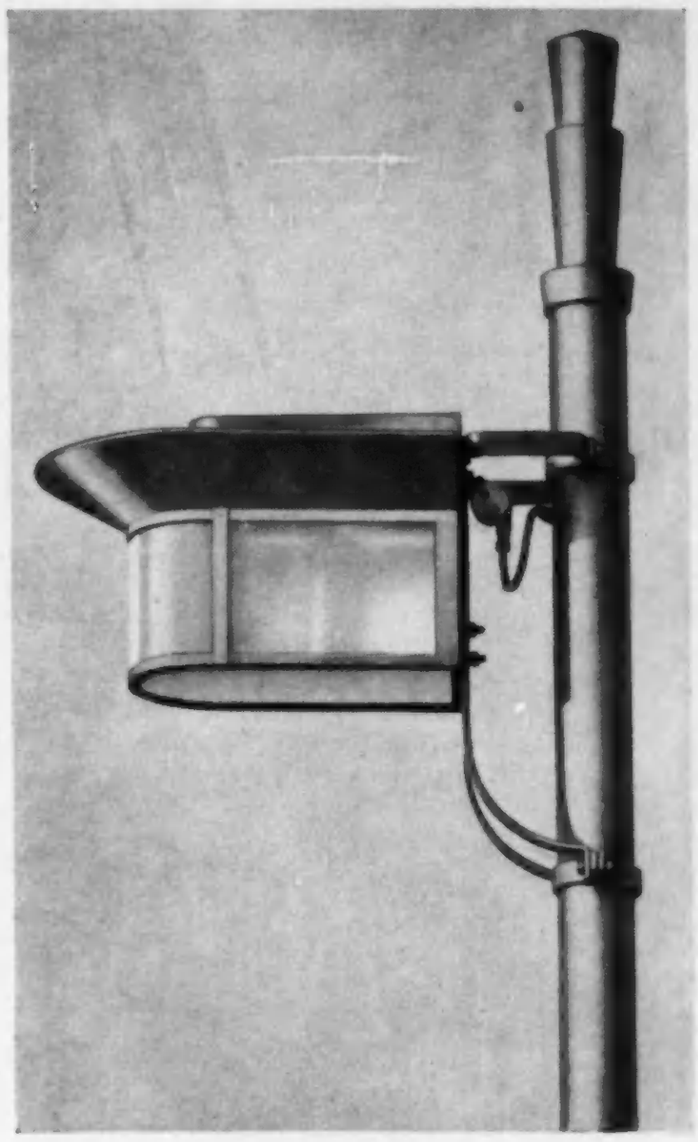


Fig. 5.—The Watford lantern.

etched lettering. By using different coloured lacquers in the same plate, multi-coloured effects are made possible.

A new type of Ripple discharge has been developed, the characteristics of which are the soft lavender colour and slow, snake-like movement of the luminous column.

FITTINGS FOR THE "OSIRA" LAMP.

The introduction of the "Osira" lamp for street-lighting has brought with it new possibilities for the fittings designer.

Lanterns designed for use with the "Osira" lamp should utilise to the fullest extent the inherent high efficiency of the lamp, the source of which is a vertical column of light 6″ long and ¼″ in diameter. The light distribution of the bare lamp shows a maximum intensity in the horizontal plane decreasing to a low value directly upwards and downwards. An efficient lantern should, therefore, supply sufficient light vertically downwards, whilst at the same time giving a wide spread distribution permitting economical lantern spacings to be used.

These fundamental considerations form the basis of design of the special fittings for the "Osira" lamp,

namely the Watford, Lewisham and Rochdale lanterns.

The optical components of the Watford lantern are two rectangular prismatic refractor plates placed so as to direct beams of light up and down the road. The refractors produce the required concentration of light, while an opal glass bend at the front of the lantern directs light across the road. The bottom of the unit is also of opal glass, thus increasing the downward intensity and providing adequate illumination below the lantern. Glare has been minimised by the use of special distributor glasses in conjunction with the refractor plates. These glasses have the effect of distributing the refractor brightness over the whole side of the lantern, thus producing a large area of relatively low brightness rather than a small area of high brightness as is common with most refractors. The distributor glasses have been so chosen that the beam directed towards the on-coming motorist is of lower intensity than the beam produced in the direction in which the car is travelling. The maximum intensities initially are 3,000 candles and 6,000 candles respectively. The pleasing appearance of the lantern by day is not lessened at night when performing its function of providing excellent street lighting.

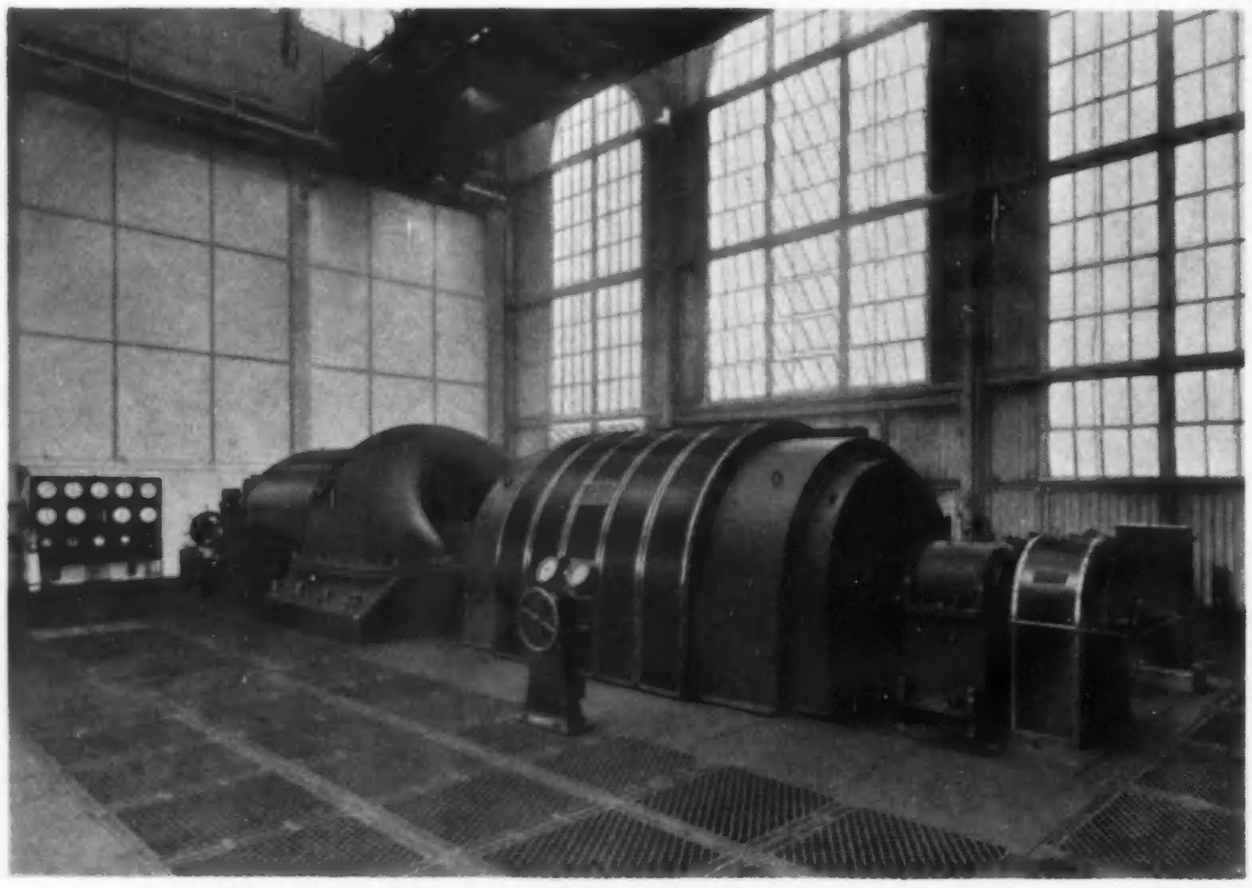


Fig. 6.—22,500 kVA 11,000 volt, 3 phase 25 cycle G.E.C.-Fraser & Chalmers turbo-alternator installed in the Stonebridge Park Generating Station of the L.M. & S. Railway.

The Lewisham lantern is another form of the Watford Road fitting, incorporating the same optical properties, but designed so that either central or bracket arm suspension can be used.

The Rochdale louvre fitting was designed primarily for use when a cheap and simple symmetric unit with a cut-off was desirable. It is not easy to obtain a cut-off with a long source, but this has been achieved in this lantern by the use of a double reflector. The whole source and a part of the bright reflector are visible at 70° to the downward vertical.

The lower reflector supplies light in a downward direction, increasing the intensity, which otherwise would be low in this direction on account of the shape of the light source. The complete cut-off of the bare lamp occurs at 82½° to the downward vertical. The distribution from this unit makes it particularly suitable for the lighting of open spaces, yards and the like, where a wide spread of light and "no glare" characteristics are required.

INEXPLOSIBLE FITTING.

An inexplosible fitting has been developed for general industrial use, the final design having been based on long-continued life-tests. The lamp and lampholder are immersed in an insulating oil, so that if any arc were formed it would be quenched, and even a hot filament exposed by the bursting of the lamp bulb, now a remote possibility, cannot ignite an explosive atmosphere outside the unit.

Fig. 7.—Four 1,500 h.p. Fraser & Chalmers steam turbines driving Worthington-Simpson centrifugal pumps at the Surbiton pumping station of the Metropolitan Water Board.

A NEW INTERIOR LIGHTING UNIT.

A totally enclosed interior lighting unit has been designed which, while having the general appearance of an enclosed diffusing unit, possesses a special distribution. The characteristics are such that a much greater proportion of the light flux is directed downwards than is usual with interior units, while the fitting as a whole has a restful appearance. This is achieved by a silvered upper portion of specially designed contour, in conjunction with an arrangement of diffusing glass surfaces, by which in spite of the high downward intensity, the brightness of the unit is kept low—below 5 candles per square inch. A special low temperature gallery is used in which the temperature of the flexible leads has been greatly reduced and the life of the insulation prolonged.

BARRETTERS.

Owing to the persistent demand for D.C. mains operated wireless receivers, a barretter has been developed for the purpose of regulating the heater current in the Osram 0.25 amp. D.C. valves. The operating voltage range of the new barretter has been so chosen that it maintains a constant current of 0.25 amp. through the series-connected heaters of four or even five valves for a variation of supply mains voltage of 200 to 250 volts. In the case of a three-valve receiver, a small additional fixed resistance is necessary, and this may well be the field winding of a moving-coil loudspeaker.

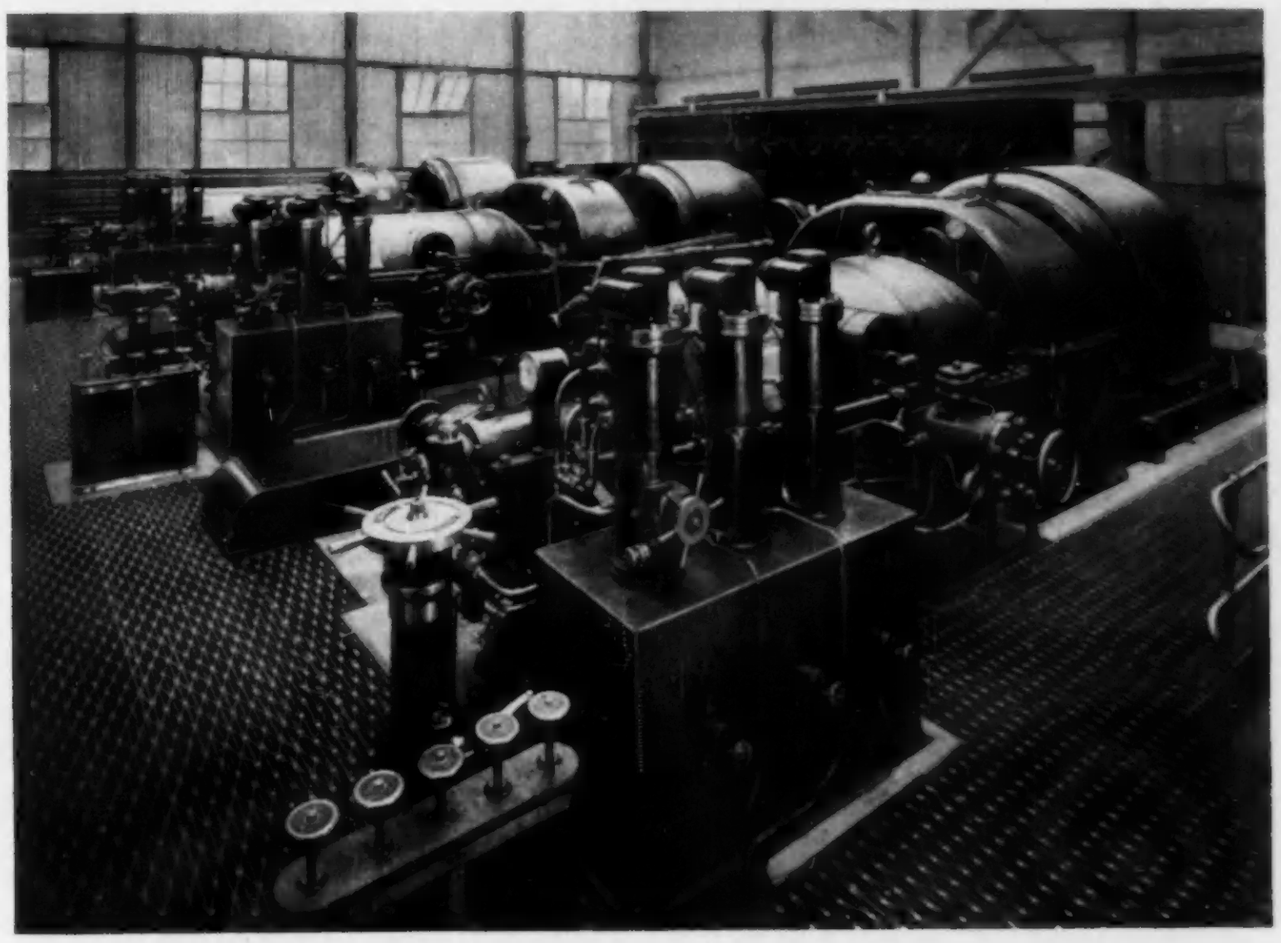


Fig. 8.—Three G.E.C.-Fraser & Chalmers 3,750 kW turbo-alternators in the power house of The Grease-proof Paper Mill Co., Ltd.

GENERATING PLANT.

Although there has been little demand for generating units of very large capacity for public electricity supply, a noticeable feature of the past year has been the increased demand for two classes of generators. The first of these comprises geared turbo sets for installation in factories where process steam is required, and the second, engine driven alternators, which are mainly for the overseas market. The industries where the greatest demand exists for geared turbo sets include textile mills, paper mills, collieries, and food and chemical factories; actually, in every class of factory where process steam is required considerable economies are being effected due to the introduction of this plant, provided that the process steam amounts to 30 per cent of that required for the generation of electricity.

A feature of interest relating to the engine driven alternators lies in the world wide extent of the demand, sets supplied during the last year or now in process of manufacture being destined for South Africa, Argentine, Palestine, Barbados, New Zealand, Cyprus, Manchukuo, India, Macao and Persia. Turbo-alternators of large capacity are also in hand for Jugo Slavia and Johannesburg; in the case of the latter, the set will be the third of 12,500 kVA manufactured by the G.E.C.

A number of motor generator sets for the British Broadcasting Company are intended for supplying filament current to the main transmitting valves. One of the sets is of unique design in that the generator is insulated from the driving motor and from earth to withstand an applied pressure of 50,000 volts maximum.

The machine, which is mounted on porcelain insulators, is driven through a special porcelain coupling provided with corona rings, and carries a motor-driven field regulator above the frame. An insulated coupling is also provided between the small motor and the spindle of this regulator. All metal parts are rounded off to eliminate as far as possible all visible corona. In addition, steps have been taken to reduce the electrostatic capacity to earth to a minimum.

A demand has arisen recently for Diesel generating sets for supplying current on railway kitchen cars for electric cooking. Two 27 kW generators are employed, both coupled to the Diesel engine. The first equipment of this kind was installed on the train exhibited by the L.M.S. Railway Co. at the Chicago Fair.

MERCURY ARC RECTIFIERS.

Improvements have been effected in the design of steel tank mercury arc rectifiers and a range of sizes

and ratings covering present day commercial requirements is available, both with and without grid control. Three units of the range completely erected and awaiting test are shown in fig. 9.

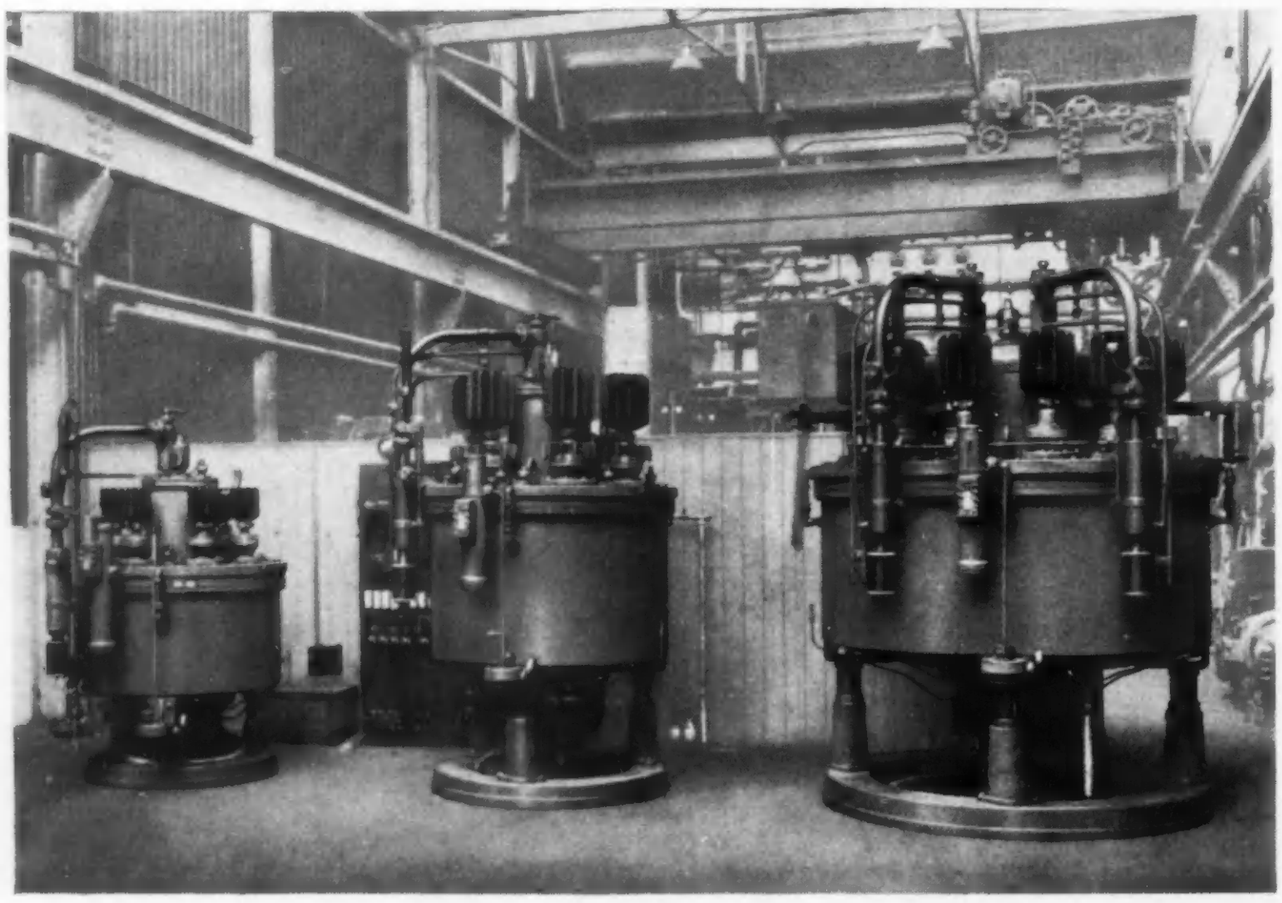


Fig. 9.—Three G.E.C. mercury arc rectifiers on test at Witton. Ratings from left to right ; 1,000 kW, 900 volts ; 2,000 kW, 3,000 volts ; 5,000 kW, 1,500 volts.

A 500 kW equipment supplied to Rotherham Corporation is of interest in that it is intended for supplying a trolley bus system. The incoming supply is at 6,600 volts 3 phase and the D.C. supply at 570/650 volts. The water cooling system is entirely self contained. The water is pumped through the rectifier cooling jackets and through an air cooled re-cooler. The diffusion pump is cooled by a separate naturally cooled system, the water circulating through the jacket and cooler by thermo syphon action; thus only occasional make up water is required.

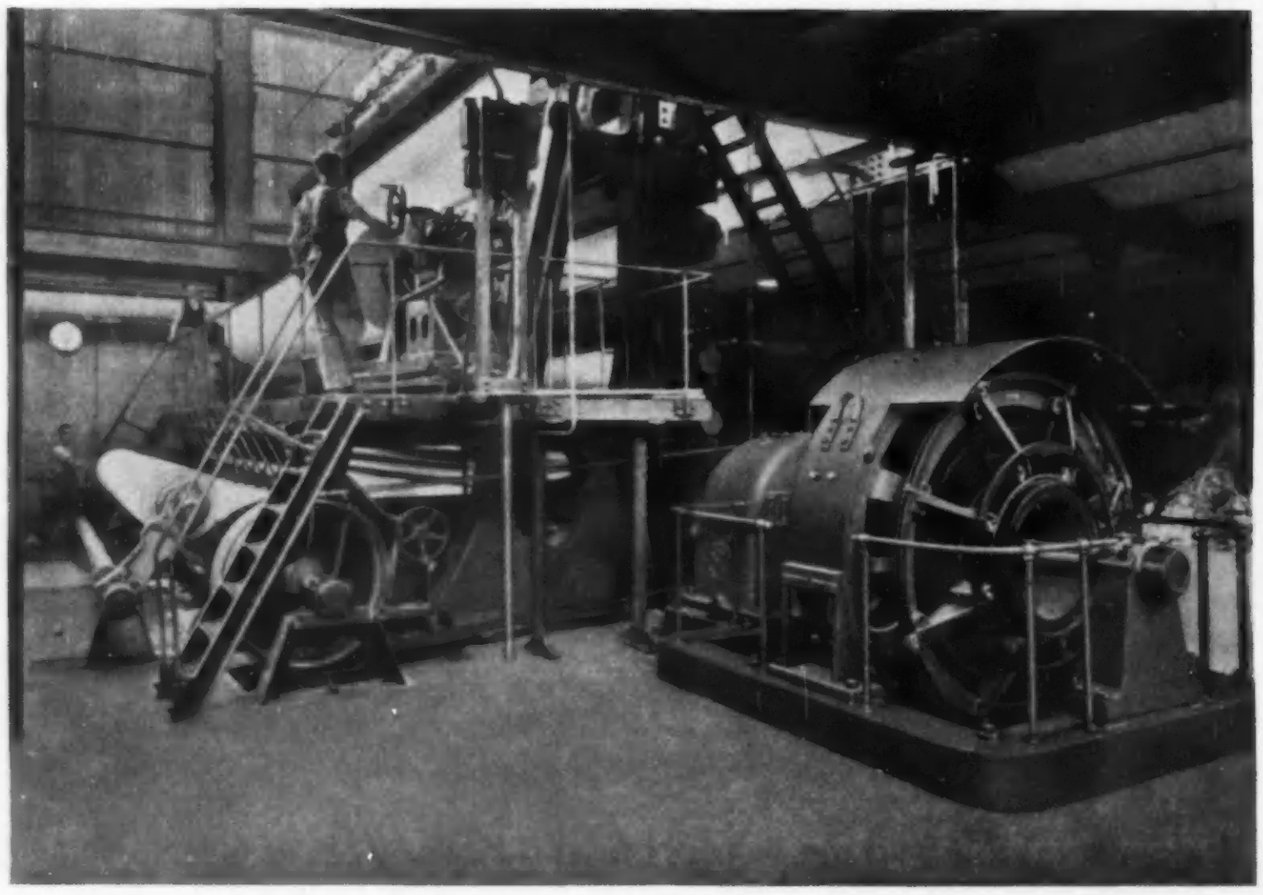


Fig. 10.—250/500 h.p., 440 volt, 225/562 r.p.m. D.C. motor, driving super calender at the Aylesford Paper Mills of Albert E. Reed & Co., Ltd.

INDUSTRIAL MOTOR APPLICATIONS.

Many industrial electrification schemes have been successfully completed. Several equipments possessing features of interest have been supplied for driving paper mill machinery, the foremost example of which is furnished by a super calender in the Aylesford Paper Mills (Kent), of Albert E. Reed & Co., Ltd. The width of the calender, which is believed to be the largest in the world, is 260 inches, and the maximum paper speed attained, 2,000 ft. per minute.

The main driving motor, fig. 10, is a direct current machine rated at 250/500 h.p. with speed variation of 225/562 r.p.m. obtained by shunt control. The motor is started by a separate motor-generator set, designed to produce a starting torque equal to $5\frac{1}{2}$ times full load torque ; it is also capable of supplying power to the main motor for "crawling" at 17.5 r.p.m. which corresponds to a paper speed of 62 ft. per minute. Emergency rheostatic braking is provided by means of a sequence of current-controlled contactors, the scheme being designed to bring the calender to rest from any running speed in not more than 7 secs.

In the same paper mill is installed a winder or reeler designed for a maximum paper speed of 3,500 ft. per minute. The only reeler in existence which is wider, is installed at the Great Lakes Paper Co., Canada. The main rolls of the winder are driven by a 120 h.p. d.c. motor having a speed variation by means of Ward Leonard and shunt control of 0/1200 r.p.m. An auxiliary 8 h.p. motor drives the riding roll, and is fed by the same Ward Leonard set by means of which, together with shunt control, its speed can be varied from 0 to 2000 r.p.m. The speeds of the main motor and the riding roll motor are electrically synchronised with one another. This winder embodies a new slitting feature in which each of the eleven knives is driven by its own $\frac{3}{4}$ h.p. motor instead of by one common motor as heretofore ;

these motors are also synchronised to give similar cutting speeds on each knife.

It is not possible to give much detail of other industrial applications but reference should be made to a few specific industries in which the use of electricity is extending. A prominent example is afforded by the sugar industry in India, motors with control gear having been manufactured for several mills. Electric pumping sets are being installed in greater numbers than heretofore, particularly for dealing with storm water, while small motor driven booster pumps (fig. 11) are increasingly required for maintaining the pressure in town mains in order to cater adequately for the demand arising from new districts which are in course of development. Motors for pump drive are also being supplied for irrigation purposes in Palestine. The motors illustrated at fig. 12, represent part of an installation recently completed in the factory of the Hull Ice Co., which affords an excellent example of the value of electricity in ice making processes. It is hoped to publish a full description of this installation in an early issue of the *G.E.C. Journal.*

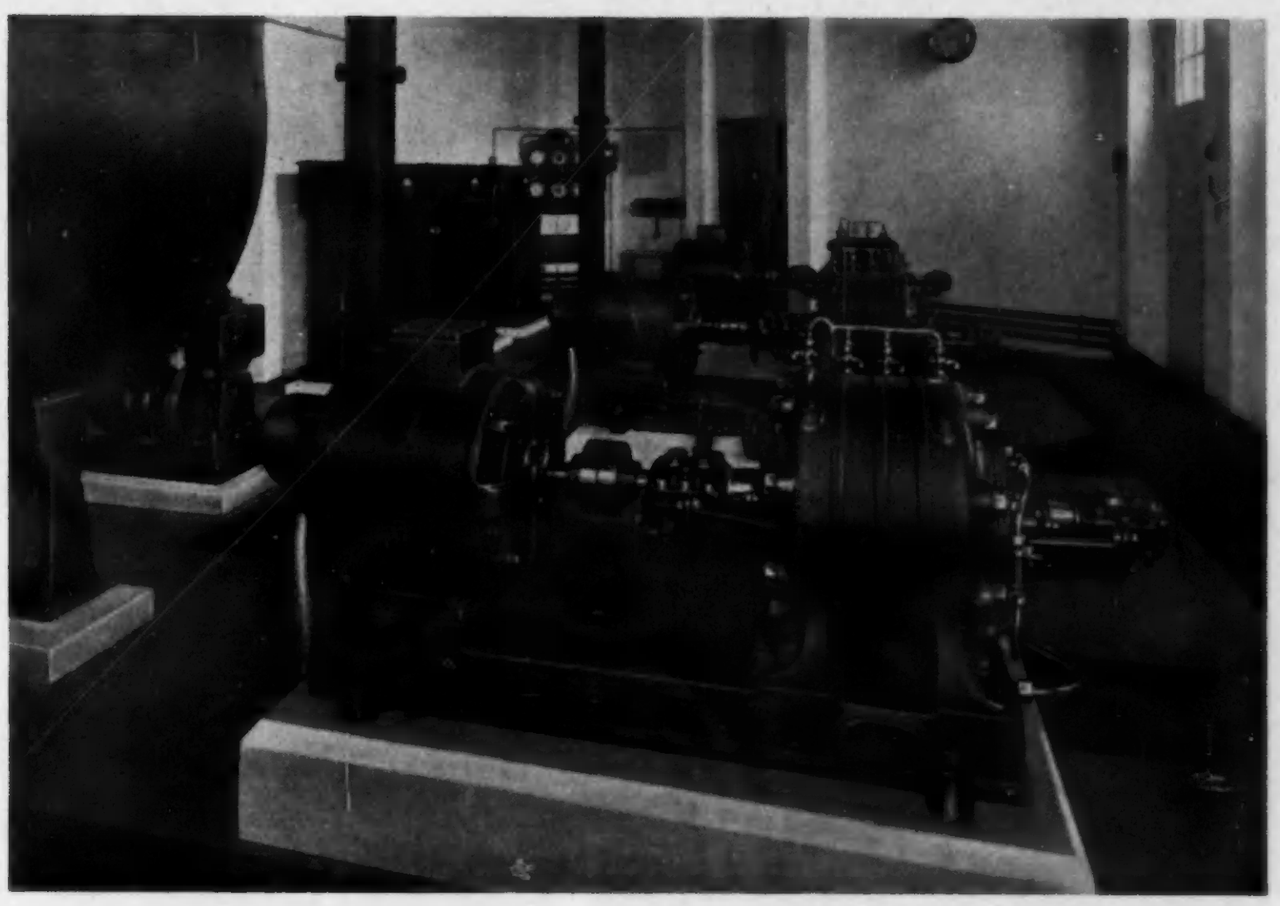


Fig. 11.—View in the Weston pumping station of the East Elloe Joint Water Board, showing three 25 h.p. 400/440 volt 3-phase 50 cycle motors driving Holden & Brooke pumps at 1,450 r.p.m. Control is automatically governed by hydraulic pressure switches.

There are definite signs of revival in the iron and steel industry and a comprehensive electrification scheme is in hand for the Whitehead Iron and Steel Co., Ltd., Monmouthshire, the equipment including a 1500 kW rotary converter and three large rolling mill motors. In addition, a 1,000 h.p. rolling mill motor is being built for a Roumanian steelworks, and both A.C. and D.C. machines for rolling mill drive in the works of I.C.I. Metals, Ltd. Reference should also be made to motors for flour mill drive in Buenos Aires, and the driving of textile machinery in the Cawnpore Cotton Mills where the electrification scheme in hand includes H.T. and L.T. switchboards, transformers, and other apparatus.

The automobile industry is continually installing electrical sets for testing purposes, the Austin Motor Co., Ltd., having recently decided to install 24 complete equipments for testing the engines of their well known "12" and "16" models. Sets consisting of three direct current machines are under construction for Moss Gears Ltd. for back axle testing, full details of which will be published later.

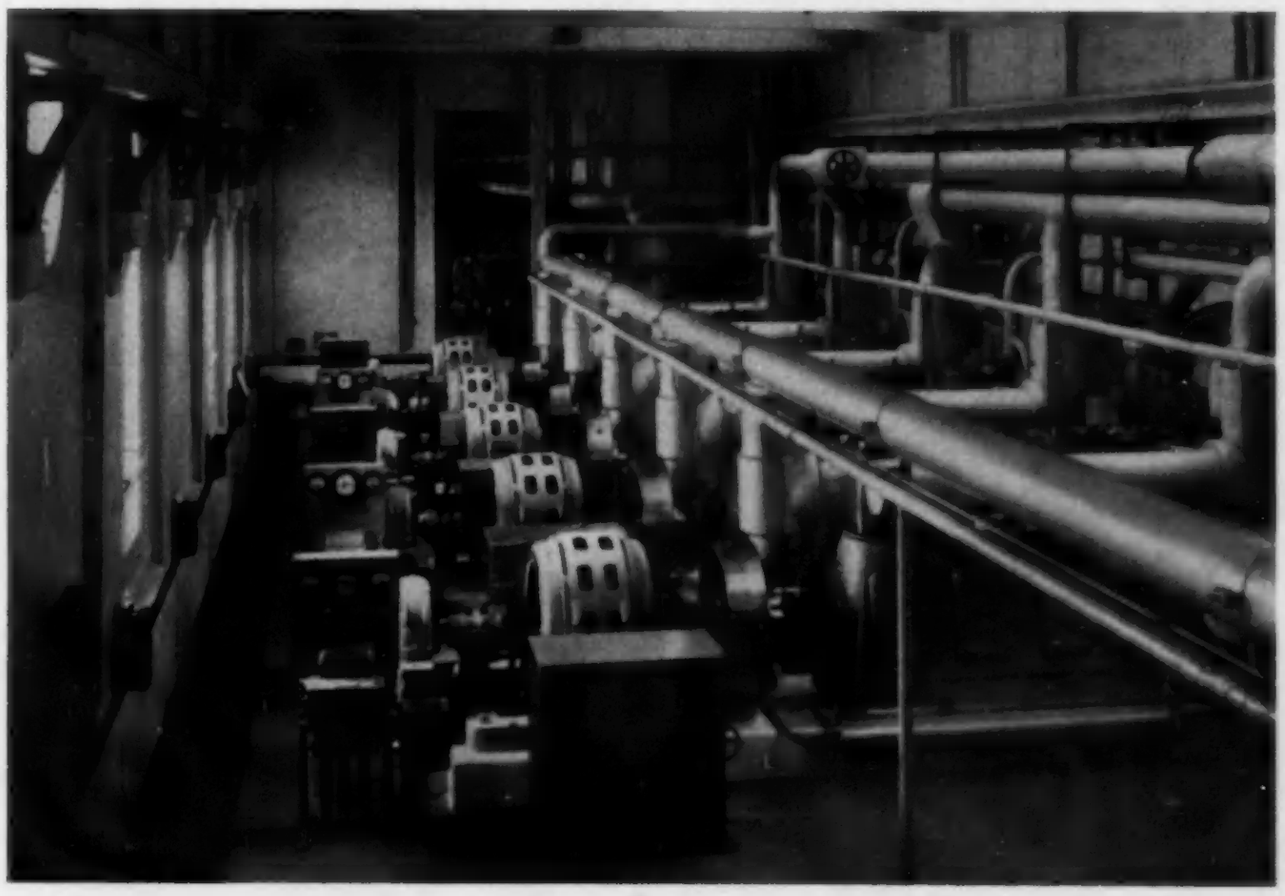


Fig. 12.—Five 380 h.p., 400 volt G.E.C. synchronous induction motors driving ammonia compressors in the factory of the Hull Ice Co., Ltd.

EXPLOSION PROOF MOTORS.

Several totally enclosed explosion proof motors, complying with Mines Regulations No. 132 and British Standard Specification No. 279, have been manufactured and tested (fig. 14). The only tests for colliery explosion proof gear which are now officially accepted are those performed by the Mines Department Testing Section at Buxton, which issues certificates for the various classes of apparatus submitted by

manufacturers. Buxton certificates have been obtained by the G.E.C. for explosion proof motors, and also various types of switchgear, to be referred to later.

MOTORS EMBODYING REDUCTION GEARS.

A range of small motor driven reduction gear units has been introduced, the outputs ranging from $\frac{1}{8}$ h.p. to $\frac{1}{2}$ h.p. Spur gears are fitted in the end brackets of the motors so that the gear is an integral part of the end bracket. Ball bearings are fitted. The unit is suitable for use on flexibly

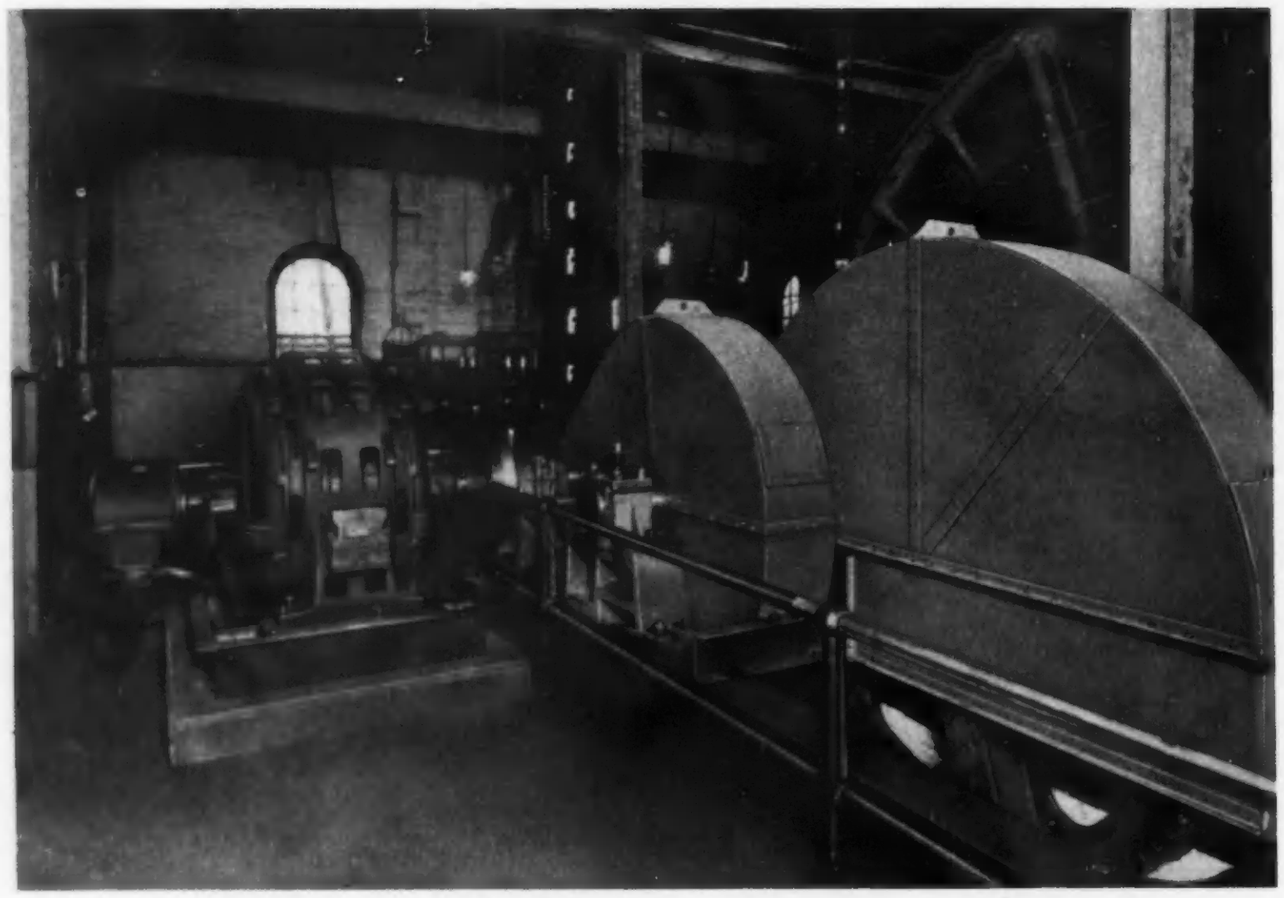


Fig. 13.—G.E.C. 250 h.p., 2,750 volt dual frequency winder motor at the Randolph Coal Co's Evenwood Colliery.

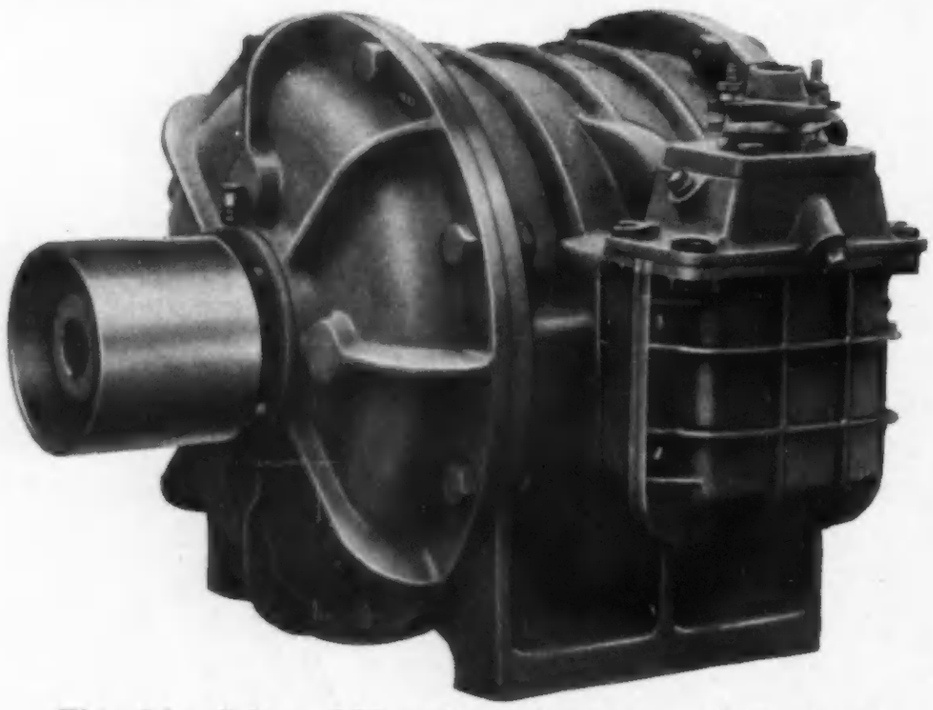


Fig. 14.—5 h.p. 550 volt explosion proof squirrel cage motor.

coupled direct drives; alternatively it may be installed for belt or chain drives without the need for an extra bearing. A typical example of the $\frac{1}{2}$ h.p. unit is shown in fig. 15.

GRAMOPHONE MOTORS.

Improvements have been made to gramophone motors, both for A.C. and D.C. (fig. 16). If desired, the motor can be supplied complete on a baseplate which also carries the pick-up arm and head, forming a complete gramophone unit, suitable for mounting in a cabinet with the amplifier. This arrangement offers the advantage that the unit is self-contained, thereby avoiding separate fixing of the pick-up. Further, there are no levers projecting over the turntable, such as would be necessary for operating the switch when the pick-up and motor are supplied as separate units.

An automatic switch is provided, which will switch off any record fitted with the usual spiral or eccentric finishing groove, the action being independent of the diameter at which the music grooves finish. The switch and pick-up are mounted as one unit on a base which is screwed to the top plate in a manner which permits the position of the pick-up to be adjusted to suit requirements without any further adjustment between the pick-up and the switch.

Improvements have also been effected in the mechanism of the automatic switch, which prevent any appreciable side pressure on the needle during playing, or at the end of the record when the needle enters the spiral groove. This point is of great importance, since the slightest side pressure on the needle causes both rapid wear of the record and distorted reproduction.

ELECTRIC DRILLS.

The electric drill is another type of small motor driven appliance which has been redesigned with

Fig. 15.—Typical small motor-driven reduction-gear unit.

gratifying results. There are three principal types manufactured (1) the "pistol," (2) the "breast" pattern and (3) the screw feed type. As will be seen by reference to fig. 17, which shows a "pistol" type drill, a particularly clean contour has been attained which allows the drill to be brought into the closest possible relation to work which may be of awkward shape.

Switches have been specially designed for the range of drills which will not break down when heavy stalling currents occur. A device is embodied which results in firm anchoring of the cable. The armature speeds of the motors are kept within reasonable limits, and the motors comply with the appropriate British Standard Specification in every respect. A very important feature results from the attention given to the handles of the drills, namely, that an operator can use them for long periods with a minimum of fatigue.

METALCLAD SWITCHGEAR.

Metalclad switchgear has continued in favour for practically all classes of installation for which it is suitable. While the general principles of design have not undergone any radical change during the past year, continual attention to detail has enabled apparatus of a very reliable type to be produced, while maintenance has been much simplified due to the accessibility of each part of the gear which requires attention. Typical metalclad switchboards recently completed are shown in figs. 18 and 19.

A new design has been introduced for performing the operation of busbar selection on load. This employs an oil immersed selector switch. The method involved is shown in figs. 20 and 21. It should be particularly noted in the latter illustration that during changeover the circuit is not broken. The selectors can be inspected by lowering the circuit breaker, the changeover switch also being isolated. Operation is effected by means of a handwheel, the stem of which is held normally in a socket on the bus coupler switch. Before it can be removed for the purpose of operating the selector switches the bus coupler must be closed; so long as it is out of the socket the bus coupler cannot be opened. When in use on a selector, the handwheel

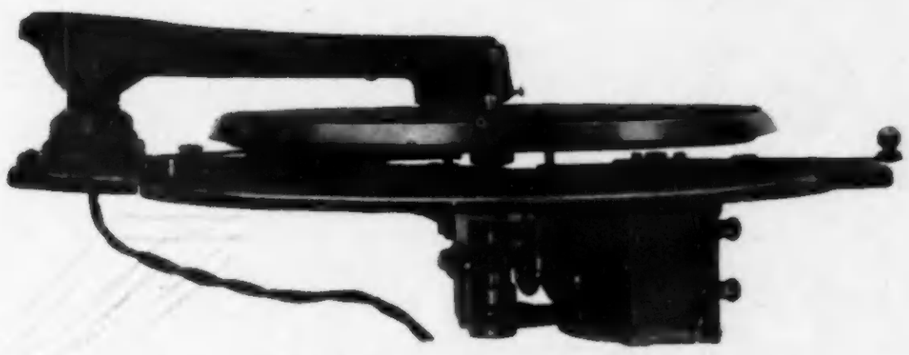


Fig. 16.—A.C. high speed gramophone motor, turntable and pick-up with automatic stop.

can be removed only when the selector is in either of the two normal positions. It is thus impossible to open the bus coupler leaving the busbars coupled through the selector switch.

VERTICAL DROP DOWN SWITCHGEAR.

An air insulated type of switchgear designated "S.V.D." which has rapidly attained a wide degree of popularity both at home and overseas is illustrated in fig. 22. It complies in every respect with appropriate British Standard Specifications, and is suitable for 11,000 volt circuits. Oil circuit breakers with maximum rupturing capacity of 150,000 kVA

Fig. 17.—G.E.C. pistol type heavy duty drill.

can be accommodated. The vertical drop-down principle is employed for isolating the circuit breaker, each unit embodying a self-contained lowering mechanism, which is fully interlocked with the breaker so as to eliminate the risk of operating the mechanism when the breaker is in the off position. A removable shutter plate is fitted which covers all "live" parts when the breaker is lowered, and the isolated position of the breaker is clearly marked on the front of each unit.

All the fundamental points associated with first class switchboard practice are embodied, including safety, reliability, simplicity and interchangeability of units of the same rating, while front access is a feature of the gear; it should also be emphasized that considerable economies are effected in floor space and headroom by its installation.

NEW HIGH POWER TESTING LABORATORY.

In view of the great importance attaching to the testing of large oil circuit breakers a new laboratory is being built at Witton in which it will be possible to test breakers when subjected to short circuits up to two million kVA at any commercial voltage.

The principal equipment will consist of a 50,000 kW, 22,000 volt alternator running at 3,000 r.p.m., a bank of three single phase transformers to provide any voltage up to 132,000 volts, banks of reactances and resistances, also suitable apparatus for timing the tripping of the test circuit breaker, the application of the short circuit, and for the provision of the super-excitation of the alternator which is highly essential for maintaining sustained short circuit currents. The breakers will be tested in a large explosion proof chamber; a complete oscillograph apparatus will be housed in a separate observation hut situated some distance from the test bay. A complete CO_2 apparatus will be installed to deal with any accidental outbreak of fire.

OIL IMMERSED SWITCHGEAR.

The oil circuit breaker (type O.D.3/2) shown in fig. 23, has been designed for outdoor purposes and should find extensive application in rural electrification schemes. It is available in a variety of forms, *e.g.* (1) as a simple oil circuit breaker for pole mounting or floor fixing; (2) equipped with an adaptor chamber for bolting direct to power transformers; (3) for ring main service, and (4) as a switchboard with air insulated busbars. When used for ring main service or as a switchboard, arrangements are made for vertical isolation of the breaker.

Fig. 18.—G.E.C. 11,000 volt, 350,000 kVA metalclad switchboard with duplicate busbars and transfer circuit breakers, installed at Duke Street Sub-station, Norwich.

The overload trip comprises a U-shaped electro-magnet which is mounted on the moving contact carrier, and is thus readily accessible. Overload settings may be adjusted by means of a screw which varies the tension of a controlling spring. Time lags which are situated in the circuit breaker hood are of the oil dash-pot type, the setting being adjusted by altering the position of the piston in the cylinder. The time lag is so constructed that it governs the operation of the overload trips, except under short circuit conditions when instantaneous tripping is obtained.

A range of oil immersed isolators has been designed for mounting on ring main switchgear units, *e.g.*, metalclad switchgear units, also the S.V.D. type gear and the outdoor oil circuit breaker, both of which have just been described. The S.V.D. switchgear unit shown in fig. 22 is fitted with these isolators which comprise an oil immersed three phase switch of the knife blade pattern giving three definite positions, "on," "off" and "earth." Arrangements are made to eliminate any danger due to the operator moving the isolator from the "on" to the "earth" position.

An oil immersed switch fuse which has been introduced is designed to carry currents up to 200 amps. on an 11,000 volt system, and has a rupturing capacity of 75,000 kVA. It can be supplied (1) for floor or wall mounting or for bolting on to power transformers; (2) as a complete switchboard with busbar chambers and cable boxes; (3) equipped with oil immersed isolators to form a ring main unit; (4) for pole mounting.

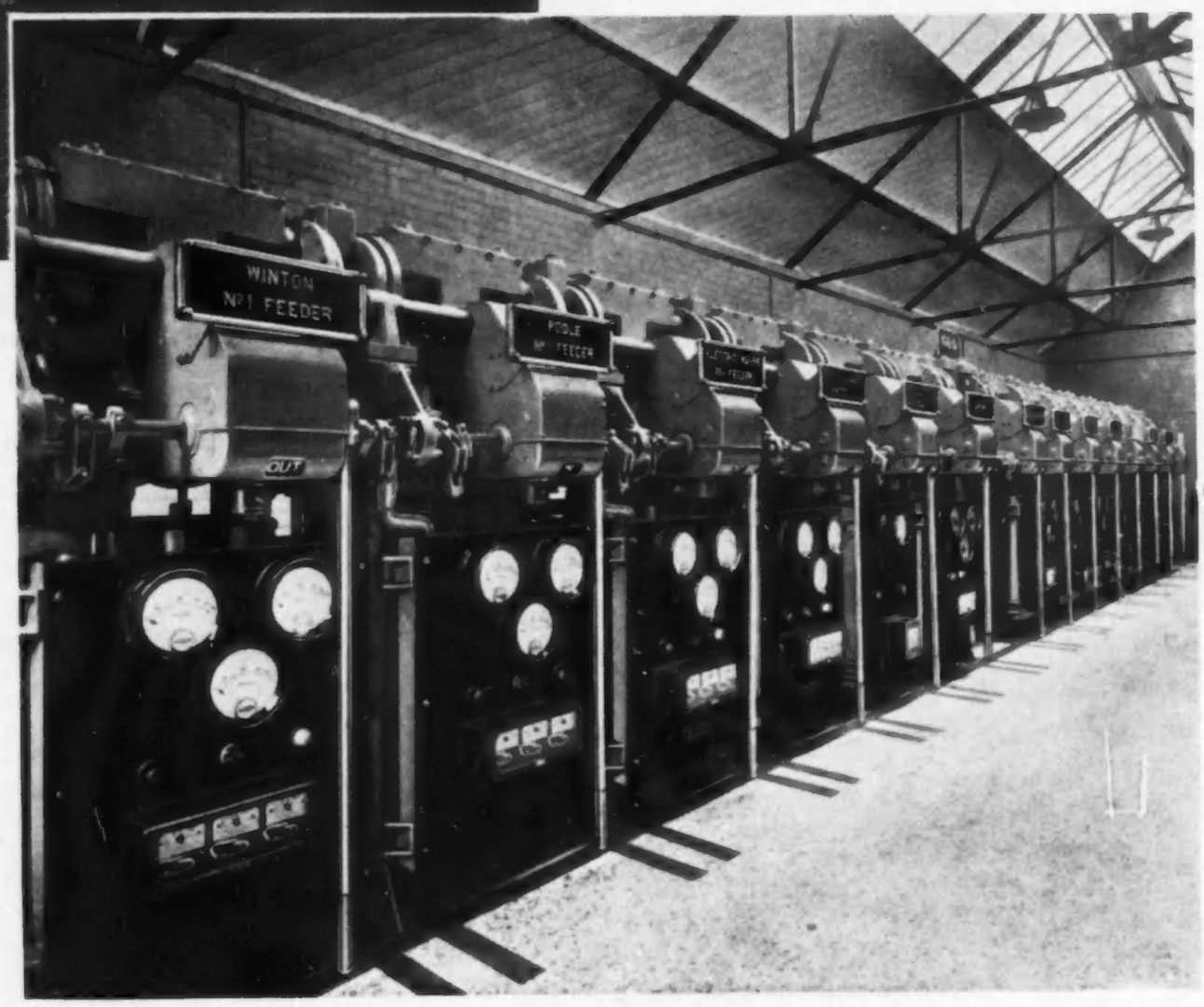


Fig. 19.—11,000 volt, 350,000 kVA metalclad switchboard with single busbars installed at the Bourne Valley Power Station, Bournemouth.

Each unit fig. 23, consists of a switch fuse chamber made up of two parts, first, a casting provided with a hinged lid, suitably interlocked with the operating mechanism to ensure that it can only be opened when the switch is in the "off"

position, and secondly, a steel oil tank which is bolted to the underside of the lid.

The fixed contacts are of the line-contact controller pattern, while the moving contacts embody the fuse carriers which are of porcelain, separated from each other by strips of bakelised paper board. The holders carry the fuse wire and are provided with slots so arranged that any arc that may form when a fuse blows is rapidly extinguished by the oil.

A feature of the unit lies in the arrangement made for rewiring the fuses. To carry out this operation, the operating handle is moved to the "off" position and the top cover raised, which permits the fuse carriers to rise through slots in the top casing. The porcelain fuse holders can then readily be withdrawn for rewiring.

The unit not only affords overload protection but can also be used as an oil switch. For this purpose, accelerating springs are provided to ensure rapid opening of the unit.

OUTDOOR SWITCHGEAR.

New demands are continually arising in connection with overhead line switchgear, now that lower voltage transmission lines are being extended in so many districts. In consequence the ranges of equipment for outdoor purposes are continually being augmented, while older designs are revised in the light of changing conditions.

The development of a liquid immersed rewirable high voltage fuse is of great importance. Its general features are shown in the drawing at fig. 24. It is the first time that a liquid fuse has been manufactured in this country which permits of re-wiring by the user. The fuse consists essentially of a short fuse element held in tension by a coil spring. These components are contained in a tube filled with a special mixture of chlorinated hydrocarbons having powerful arc extinguishing properties and high dielectric strength, which remains effective over any range of temperatures encountered in practice. The action of the spring gives a high speed of break, and the arc extinguishing properties of the liquid ensure positive action and high-rupturing capacity.

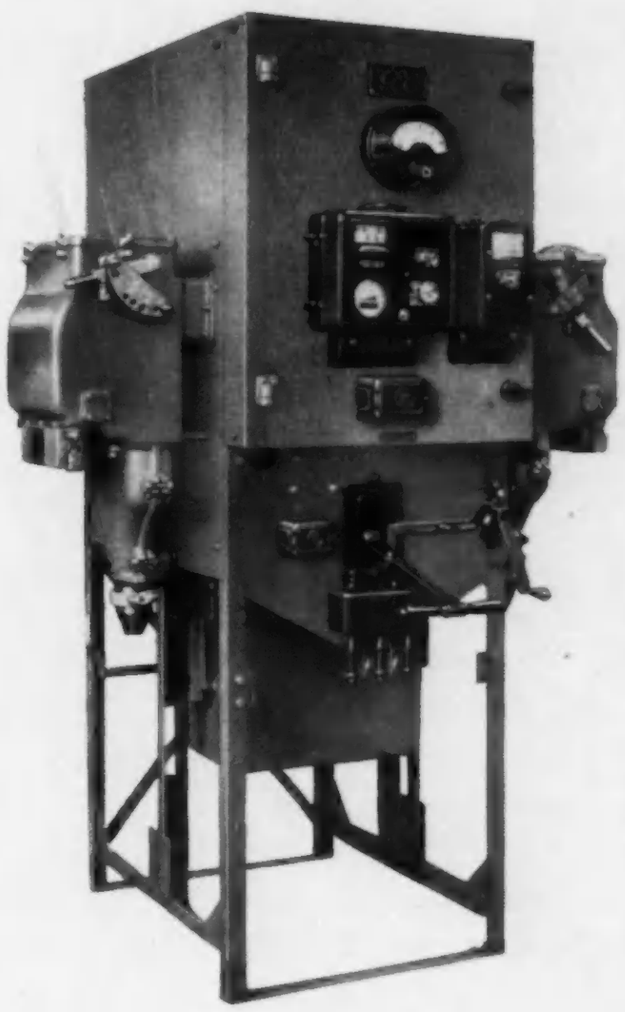


Fig. 22.—Typical 100,000 kVA 11,000 volt G.E.C. cubicle type ring main unit with vertical drop-down isolation of circuit breaker.

Special attention was directed to the importance of lightning arresters during last summer, owing to the prevalence of severe lightning storms in many parts of the country, and the demand for effective units has been marked. This demand has been met by a new line of arresters which has yielded satisfactory results. The type of arrester is of a very simple description, and is based upon the instantaneous valve action of a furnace

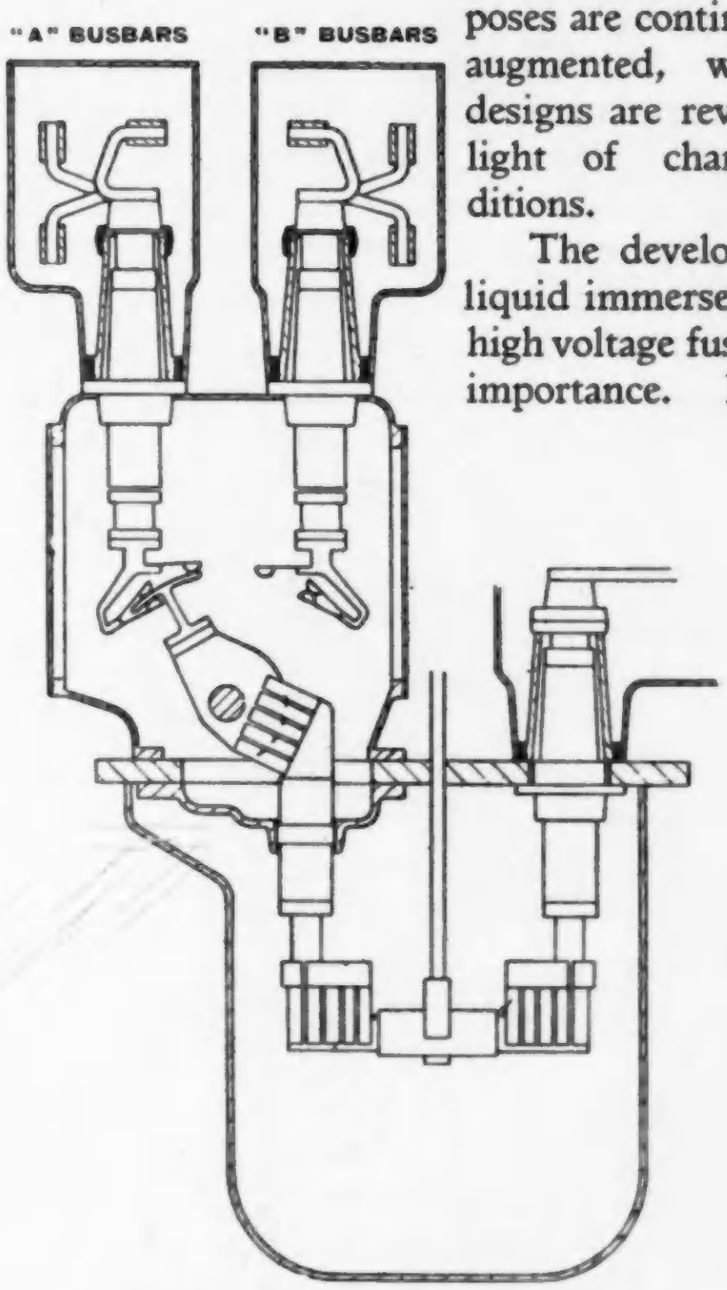


Fig. 20.—Diagram of oil-immersed selector switch for G.E.C. duplicate busbar metalclad switchgear from 250,000 to 750,000 kVA.

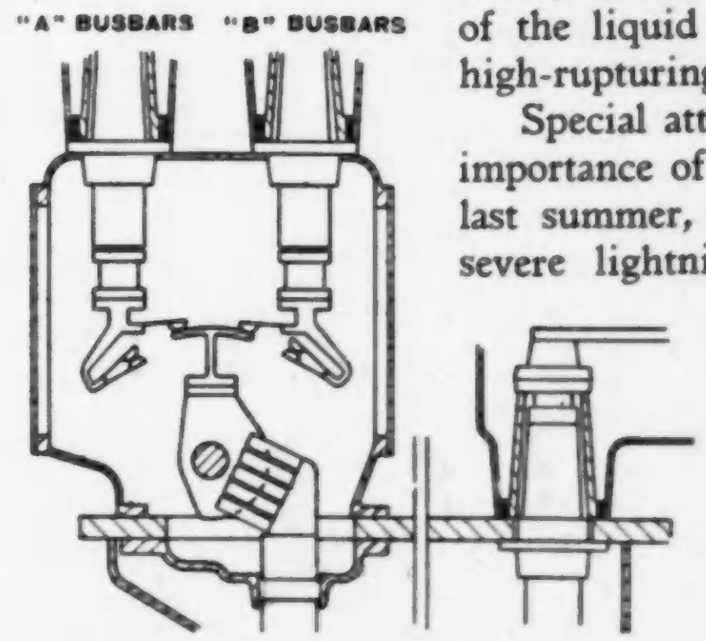


Fig. 21.—Diagram of selector switch showing that circuit is not broken during change-over. The switch cannot remain in this position.

product, which acts as an insulator at normal voltage, but offers a rapidly diminishing resistance as the voltage rises, thus affording a very low resistance by-path for the over-voltage surge. The unit was previously developed for low voltage circuits only, where it met with success. The principle has now been extended to high voltage installations up to 11 kV, three additional models having been developed.

AIRBREAK IRONCLAD SWITCHGEAR.

In view of the wide demand existing for small composite type ironclad switchboards for controlling power and lighting circuits, a range of standard parts has been produced which enables such boards to be built up in an extremely short time and with great ease.

The range of house service switchgear has been augmented, and ironclad switches and switch fuses are available with a wide variety of ratings. Two switches for particular purposes should be mentioned. The first, for use in conjunction with Neon sign installations, is a locked switch which is so designed that the operating key can be removed or inserted only when the switch is in the "off" position, the same key being used to lock the cover of the switch, so that the operator can work on the high tension Neon installation in safety. The second switch

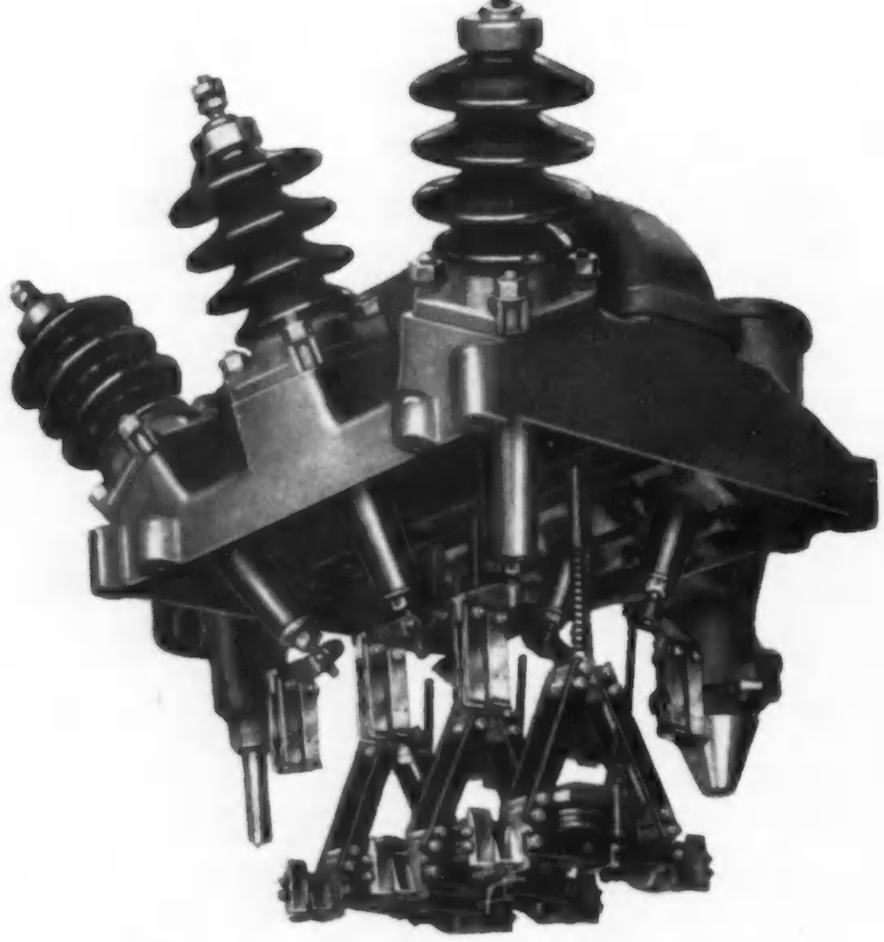


Fig. 23.—Interior view of an 11 kV, 75,000 kVA outdoor oil circuit breaker for pole mounting.

referred to is a 30 ampere cooker control switch of which there are two patterns, one with a 5 ampere plug for a kettle sub-circuit, the other with a 15 ampere plug for the same purpose. The switches are of pleasing appearance, particularly in vitreous enamel finish.

AIR BREAK CIRCUIT BREAKERS.

The increased use of a small automatic switch to replace the ordinary switch fuse on small power and lighting installations has led to the production

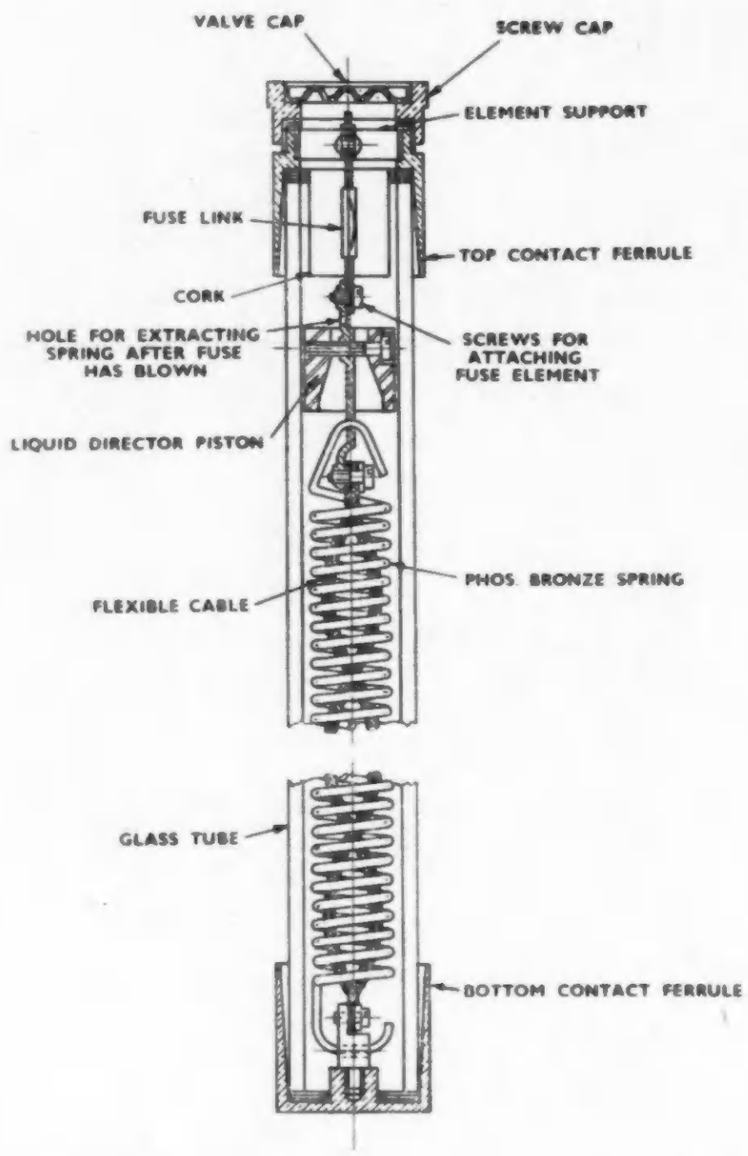


Fig. 24.—Diagram showing construction of the new G.E.C. re-wirable liquid-immersed fuse.

of the "Elf" circuit breaker, which gives a high breaking capacity. The breaker consists of a switch with a magnetic overload attachment, and a separate magnetic blow out. This provides more efficient quenching than in models where the magnetic circuit is used for both the overload and the blow out; this new pattern of breaker is made in either single or multipole types, and is fitted with a thermal delay device arranged to give an inverse time characteristic. This device is essential to prevent the circuit breakers tripping out when small motors or gas filled lamps are switched direct on to the line. A shunt trip can also be fitted for remote operation, and an auxiliary switch incorporated for bell alarm circuits, etc.

FLAMEPROOF SWITCHGEAR.

Developments in flameproof gear have continued, for all but the largest pieces of apparatus, upon the principle of designing the enclosure to withstand the full pressure of an internal explosion. This policy has necessitated stronger enclosures, the increased cost of which, however, is largely off-set by the absence of special vents, which were characteristic of earlier practice.

Reference was made earlier in this article to motors which had received the Buxton test certificate issued by the Mines Department. In addition, several items of G.E.C. mining switchgear have received this certificate.

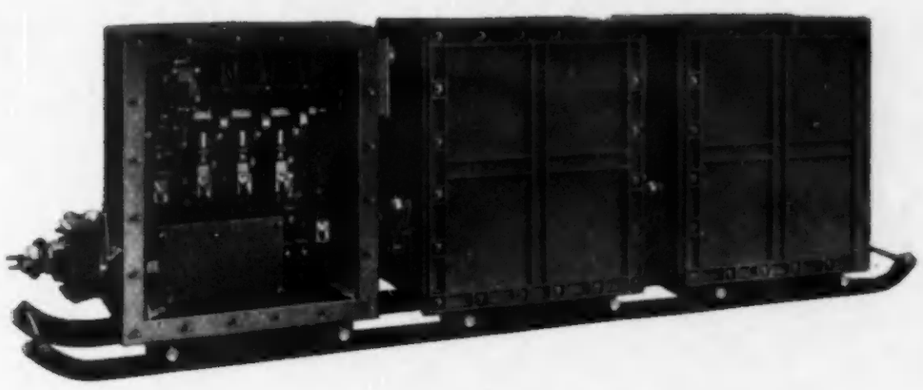


Fig. 25—G.E.C. automatic gate-end flameproof switchgear for collieries.

An interesting example of flameproof control gear is shown in fig. 25. This consists of an assembly of three automatic gate-end units for controlling a coal cutter, loader and conveyor, respectively. It will be seen that the enclosures are unvented, the ribbed cover being screwed hard against the flanges (which are 2" wide) by means of fixed studs and shrouded nuts. The three units are connected together by means of a bus-bar chamber running the length of the back and ending in the trifurcating box shown on the left of the illustration.

Trailing cables emerge from similar sealing boxes at the back of each unit, and lead to the coal cutter or other controlled apparatus. Provision is made for the usual protection against the failure of the trailing cable insulation by means of a 25 volt

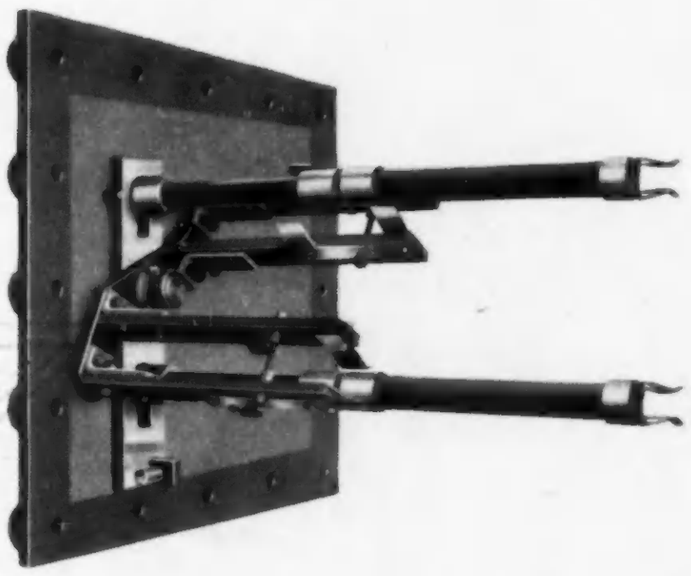


Fig. 26.—Underside of cover of flameproof colliery lighting unit showing fuses.

auxiliary supply derived from a small transformer on each panel.

A further interesting colliery equipment is the flameproof portable lighting unit, an external view of which is shown in fig. 27. This consists of a single phase step-down air cooled transformer with switch and overload protective gear. The high voltage supply is introduced through fore and aft sealing boxes, by means of which the unit is inserted in the high voltage cable;

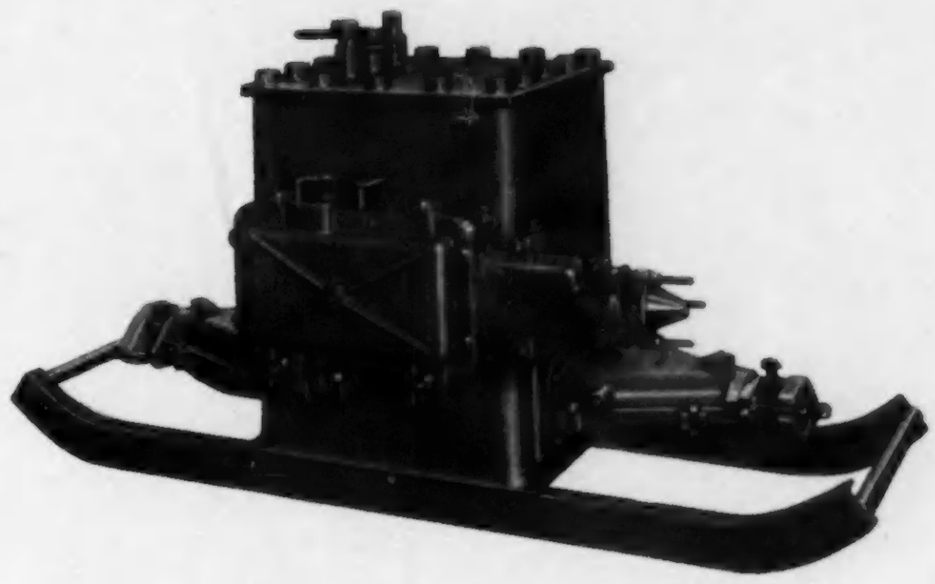


Fig. 27.—G.E.C. Flameproof colliery lighting unit.

while the low voltage current is taken off from the sealing box on the side through a flameproof switch-fuse unit mounted in a separate enclosure. The protection of the high voltage circuit is effected by means of high capacity fuses specially designed for the purpose, which fit into the two cylindrical holders mounted on the right of the transformer. The fuses themselves have been removed from the enclosure together with the cover, and are shown separately in fig. 26, which also enables the method of insertion, isolation, and interlocking to be clearly seen. They are among the several new high voltage patterns which have been developed during the year, and are capable of breaking 15,000 kVA each at the rated voltage of 3.3 kV. The arc is effectively damped out by means of a granular filling, and thus no material of an inflammable or poisonous nature is introduced. The fuses are attached to insulated holders so that while they can be withdrawn without disturbing the cover, at the same time they are so interlocked that such withdrawal is not possible unless the high voltage isolating contacts and the low voltage switch are open.

A particularly large control equipment, the whole of which is flameproof, is shown in fig. 28. This was supplied for the fully automatic operation of a 135 h.p. 2,750 volt vertical slipring motor driving a pump. It is governed by means of a float switch situated in a reservoir above the ground, about 4,000 feet distant. No less that 12 separate flameproof enclosures are included in the assembly, their cubical contents ranging from 16.5, 14, 13 and 10 cu. ft. in the case of the four main chambers, to somewhat less than 1 cu. ft. each for the remainder. The total height is 7ft. 6in.

The various chambers comprise first, a rotor contactor cubicle, containing a number of 150 amp. double pole contactors connected in the slipring circuit and provided with mechanical time element

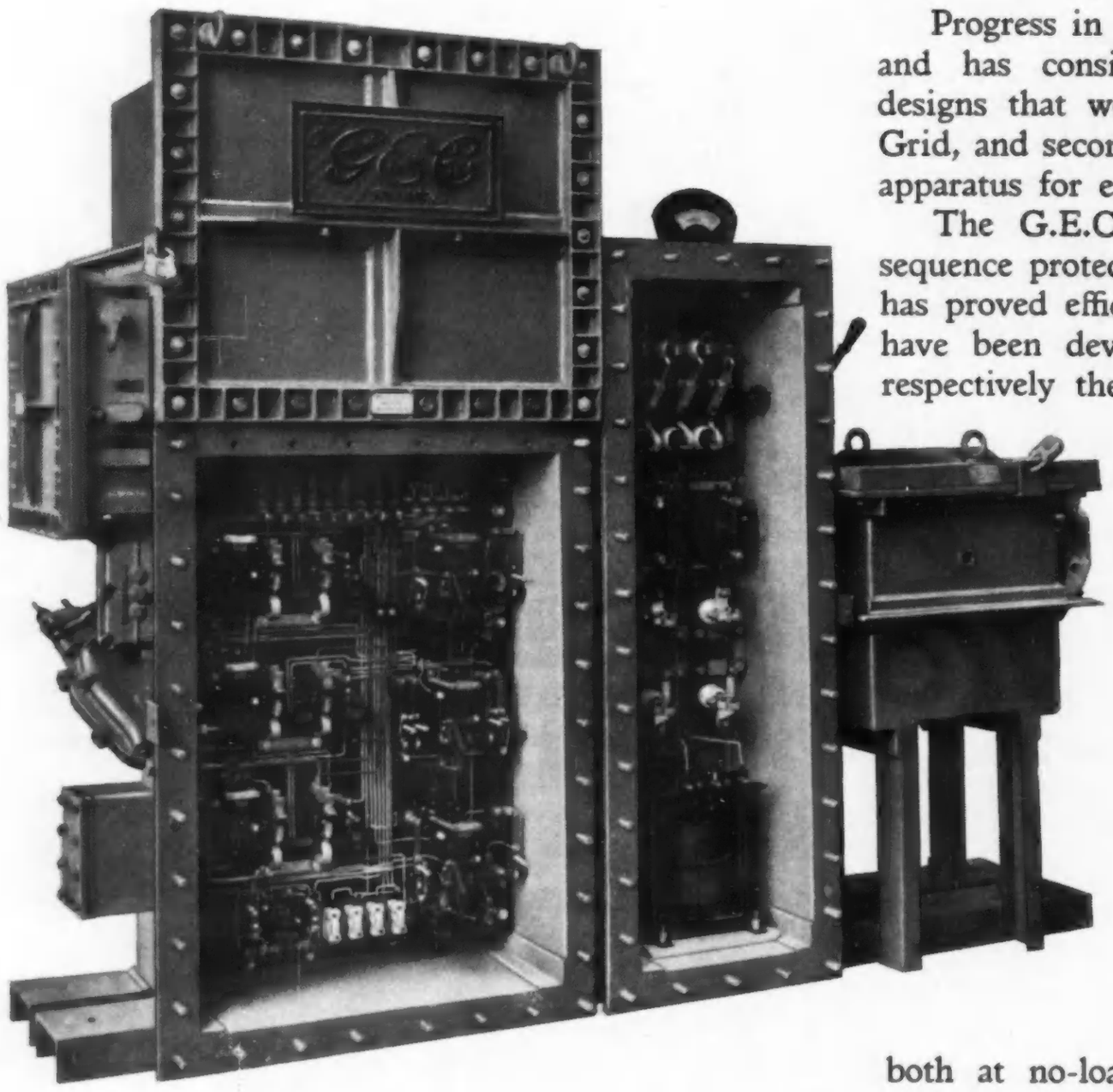


Fig. 28.—G.E.C. Flameproof control gear for float switch operation of 150 h.p. motor driving pumps at a colliery.

accelerating relays; a rotor resistance cubicle above this; an H.V. cubicle in the middle; an oil immersed stator contactor cubicle on the right; and an overload cubicle, a push button box, and six terminal boxes at various positions on the equipment. In addition to the usual provision for starting up and shutting down the motor in response to the variations in the reservoir water level, there is an interlock for delaying the starting of the pump from 30 to 40 seconds in order to enable the flushing solenoid valve to prepare the pump for action. Means are also provided for preventing the motor from continuing to run should the supply in the sump give out for a longer period than 30 seconds.

All the enclosures are of welded boiler plate except the small push button box, which is of cast iron. They are all totally enclosed with flanges up to 3" in width, bolted solidly together. The four larger components were individually subjected to stringent flameproof tests in the Explosion Testing Station at Witton Works, and passed the tests in the most explosive atmosphere of lighting gas containing more than 50 per cent of free hydrogen. In addition, the oil immersed unit passed its tests with the most explosive mixture of pure hydrogen both inside and outside the enclosure.

FAULT PROTECTIVE GEAR.

Progress in protective gear has been continuous and has consisted, first of manufacturing new designs that were evolved in connection with the Grid, and secondly, in designing new and improved apparatus for existing schemes.

The G.E.C. patented type of negative phase sequence protection which was mentioned last year has proved efficient in service. Two types of relay have been developed for the purpose, employing respectively the balanced beam and the balanced disc principles. In view of the great sensitivity required for the first installation in South West England, the latter type was adopted. These relays have been working successfully in South West England for the greater part of the year, while the scheme was subsequently adopted for the Kirkstall to Harrogate feeder, and also the Blackburn Meadows to Neepsend line, both of which included transformers in their length.

The sensitivity obtained has been as good as 10 per cent, both at no-load and normal full load, rising continuously for overloads according to the well-known biassing characteristics, and giving complete stability.

Fig. 29.—Parallel interconnector relay with cover removed.

This disc type of relay is a derivative of the vertical spindle disc relays designed for generator protection, based on McColl patents and is more especially suited for marine conditions and other cases where pitching and rolling are to be expected. Relays of this type have been fitted to the Q.T.E.V. *Queen of Bermuda*, following their successful performance in her sister ship the Q.T.E.V.

Monarch of Bermuda. The chief advantage of this type over the plunger pattern is, first, the ease with which the bias can be adjusted, and secondly, the fact that a constant air gap is maintained during operation, causing the setting to remain constant during the movement of the relay. If, therefore, the latter be exposed to vibration, there is no tendency for the operating pull of the relay to increase after the movement has begun, causing the contacts to be pulled improperly together. An adaptation of this form of relay for the protection of straight feeders was completed during the year, for use on overhead E.H.V. transmission lines.

A new type of parallel feeder relay has been completed, in which the method of adjusting the bias has been much improved. In addition, not only is very fine adjustment of the biassing magnet possible by means of a micrometer head, but this can be accurately calibrated by means of a readable circular scale. The relay is shown in fig. 29.

The principal drawback of feeder protective schemes employing pilots is the high cost of the latter. An important method for reducing this is to employ auxiliary conductors for telephony in addition to their normal function. In co-operation with the G.E.C. Telephone Works, schemes have been prepared for operating telephones from the pilot wires of any of the G.E.C. protective systems, including those of the McColl and Kapp-Carrothers types. Demonstrations fully representative of practical conditions have been arranged during the year and have proved conclusively that the telephones do not cause the slightest interference with the protective gear, and in their turn are quite uninfluenced by the latter, even when the protective gear is tripping on a fault.

Fig. 30.—Aluminium oxide static earthing device for transformers.

The Kapp-Carrothers scheme has been put into service on five lines in the Stockport district, and has also been installed on two lines on the North West Coast. An important improvement has been effected in the scheme, in the form of a rearrangement which keeps the pilot wires short circuited until the actual fault or through-fault occurs. The great advantage of this is that when Post Office pilots are employed, the gear cannot be caused to operate improperly through a G.P.O. linesman applying a testing voltage to any part of the pilot circuit.

Considerable research has been devoted to other schemes, resulting in definite improvements. A large number of "restricted earth leakage" schemes for protecting Grid transformers have been designed and placed in commission, with successful results. Schemes based on McColl patents have been further developed, and minor improvements effected in the design of the relays and other equipment.

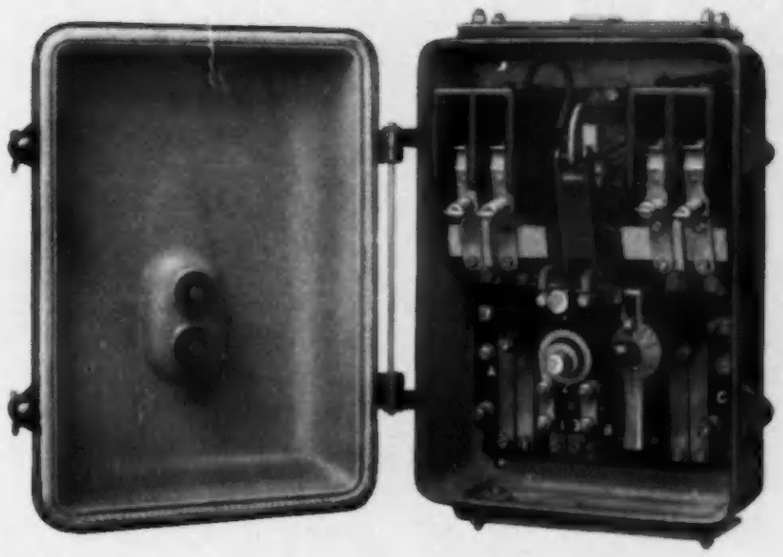


Fig. 31.—Automatic direct-to-line starter with thermal overload trips for motors up to 15 h.p. at 440 volts.

AUTO-RECLOSE OIL CIRCUIT BREAKERS.

A simple auto-reclose device has been designed by means of which an outdoor oil circuit breaker may be put into commission again after it has opened due to an overload. The device can be mounted on the same pole as a pole mounting oil circuit breaker, and embodies a motor for operating the switch. When the latter trips it is reclosed after the expiry of a pre-determined time, and if the continued existence of the fault causes tripping within the next few seconds, the breaker can be reclosed up to three or four times. If, however, the breaker remains closed at any operation within this number for a specified period, such as 60 seconds, the effect of the previous operation is cancelled. The design is rendered particularly simple through the motor being employed as the time element device, instead of this being provided separately by the introduction of dash-pots or other mechanism. This feature has also rendered the apparatus economical in price.

ALUMINIUM OXIDE EARTHING DEVICE.

In order to comply with the Home Office Rule that an earthing device or its equivalent must be employed to prevent the low voltage side of a trans-

former from being charged from the high voltage winding, a distinctive pattern has been designed relying upon the properties of aluminium oxide which is now being fitted as standard (fig. 30). The characteristic of the oxide film is that it constitutes an insulator at normal voltages, but upon the potential rising above a given critical value, it becomes conductive and can discharge an over-voltage. The principle lends itself to constancy since it is not affected by the humidity of the air as is the case with paper or perforated mica; while its mechanical properties are good.

The smallest of the equipments is for transformers of capacity lower than the above. The apparatus is spring-operated, the rotation of a motor compressing a number of powerful springs which store up the requisite energy. The springs are then released causing the switches to change over rapidly and providing quick-make-and-break characteristics. In this design, it has been found practicable to work without diverter switches, the various selector switches being given the full breaking capacity required, and this simplification has produced a very compact design.

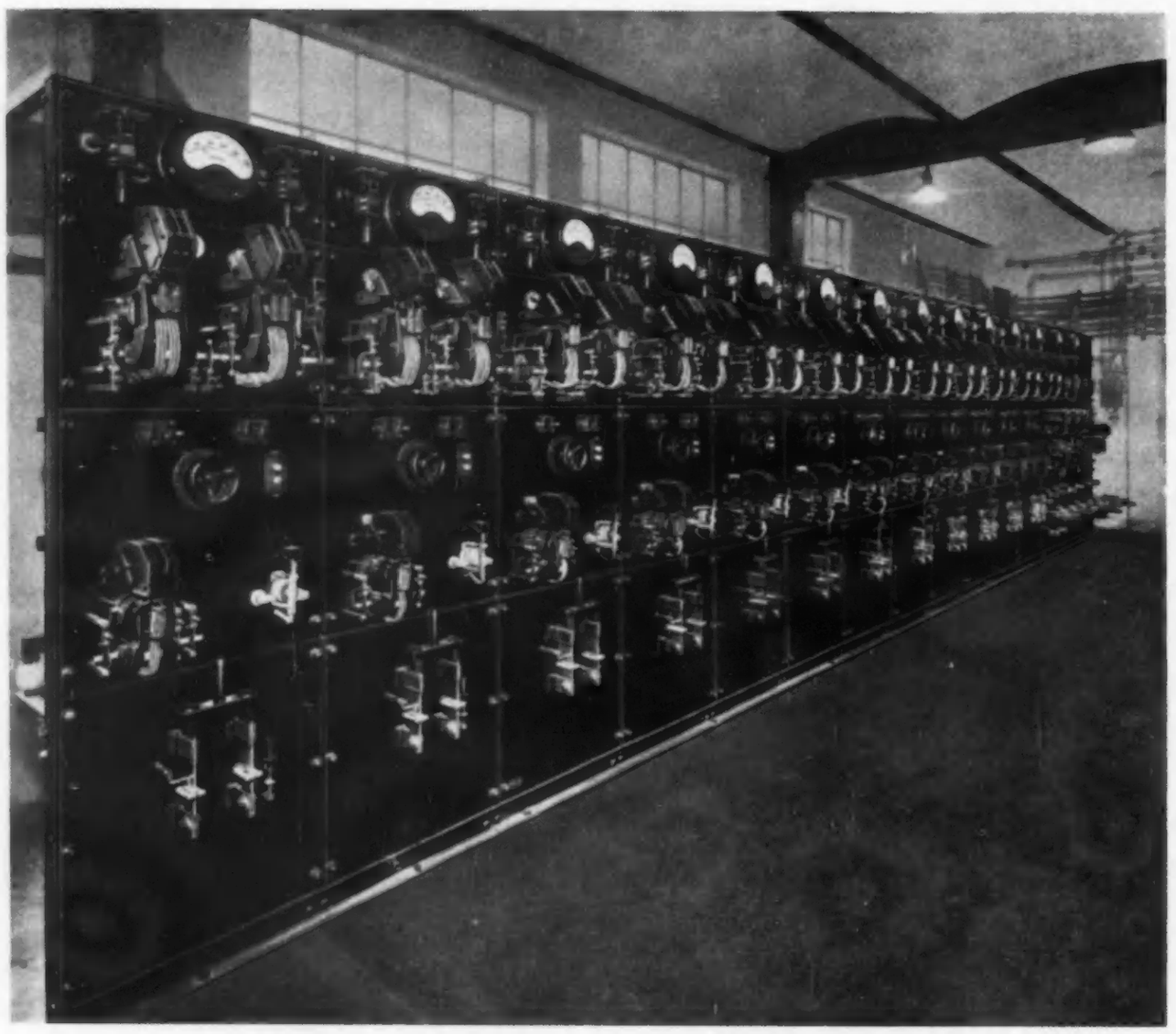


Fig. 32.—400 volt D.C. plural starter switchboard installed in the Aylesford Paper Mills of Albert E. Reed & Co., Ltd.

In view of the need for a small pattern of regulator suitable for low voltage rural lines, which will enable small villages or even individual farms to be given a supply at approximately 400 volts, a compact regulator has been designed capable of limiting the voltage variation to 2 per cent instead of the 10 per cent variation usually involved for a supply of this nature. The regulator comprises a torque motor energised by the voltage of the line itself, which directly operates tap changing contacts on an auto-transformer. An even simpler design, of the "tail and booster" type, is being developed which is for installation at the end of a distribution line and is operated in accordance with load demands at that point.

AUTOMATIC VOLTAGE REGULATION.

Much attention has lately been devoted to the subject of automatic voltage regulation, and ranges of apparatus are available for meeting the varying needs of power systems in order to ensure constant voltage at consumers' terminals.

One of the methods in general use is that involving transformer on-load tap changing equipment. Three designs of apparatus have been manufactured according to the capacity of the transformer which they are intended to control. The largest of these is that designed for grid transformers, described in the *G.E.C. Journal*, Vol. II, No. 3. For the lower ranges of transmission voltages up to and including 11,000 volts the equipment is of a type shown at fig. 34. It is suitable for transformers from 2,000 kVA up to 12,000 kVA. Operation is by means of a falling weight instead of the flywheel method employed in the larger size of gear.

SUPERVISORY CONTROL GEAR.

In many cases completely automatic voltage regulation is not desirable, many engineers desiring that control should be supervised. For this purpose methods of supervisory control, referred to in the *G.E.C. Journal* on several occasions (*e.g.*, Vol. II, No. 3), have proved highly successful. Supervisory control gear is now in course of manufacture for Winchester Corporation which will include amongst its functions the control of transformer tap-changing apparatus. In addition, the gear will provide for (*a*) the remote indication of the position of h.t. feeder switches, busbar voltage and transformer current, and (*b*) telephone communication.

A further supervisory control scheme for Ipswich Corporation will perform somewhat similar functions including the operation of transformer on-load tap changing gear.

AUTOMATIC FREQUENCY CONTROL SCHEME.

A successful scheme for controlling the frequency of a power station has been evolved and put into practical operation. Its use is to be found in such

cases as the operation of synchronous clocks. The principle is that every two seconds the frequency is corrected in comparison with a standard clock, and any slight divergence that may have occurred during that small interval is made good by directly adjusting the steam valve of the turbine concerned. Being a step-by-step integrating device, it is not subject to hunting troubles which have characterised other designs. It may be used for any number of units functioning in parallel, and on interconnected systems. The apparatus is relatively simple, and embodies the new "Twyntorq" motor for transferring the movement.

POWER FACTOR CONTROL EQUIPMENT.

The equipment for a novel control scheme has been supplied to the South African Iron and Steel Corporation who purchase some of their power in bulk from the Pretoria Municipality and generate some in their own power station at Iscor.

This scheme involves the control of the turbo sets in the Iscor power station so that the power drawn from Pretoria is as far as possible constant in magnitude and supplied at unity power factor.

A master power factor relay on the incoming supply from Pretoria makes contact in one direction or the other if the power factor of the supply departs from unity. The operation of these contacts through suitable relays increases or decreases the excitation on the Iscor station alternators so as to correct the divergence from unity.

There are three 3,000 kVA turbo-alternators in the Iscor station and it is necessary to ensure that as many as may be running at any time share equally the wattless current between them. This adjustment is accomplished by the operation of idle current relays on each machine. The contacts of the relays are arranged to operate in conjunction with the master power factor relay to secure the desired object.

In order to control the load input from Pretoria it is necessary to adjust the settings of the turbine governors. A master load relay is used for this purpose, but since the voltage and power factor of the Pretoria supply is sensibly constant the load relay takes the form of a current regulating relay instead of a wattmeter relay. The master load relay makes one of two contacts, if the supply from Pretoria departs from the predetermined setting, and through timing relays causes impulses to be given to the governor speeder motors in the correct direction to correct the load distribution between the Iscor and Pretoria power stations. Load sharing current regulating relays energised from each alternator operate simultaneously through these timing relays to maintain equal load distribution between the alternators in the Iscor Station. Arrangements are made for the correcting impulses given by the timing relays to be of a longer or shorter duration according to the amount of correction necessary.

The equipment is fully protected and interlocked to guard against faults, and limit switches operate to give an alarm if the adjustments to either the field or governor gear causes this apparatus to operate near the limits of possible adjustment. Further limit switches prevent over-running. A low load relay operates to prevent further load adjustments if the load on the Iscor Station falls to a very low value.

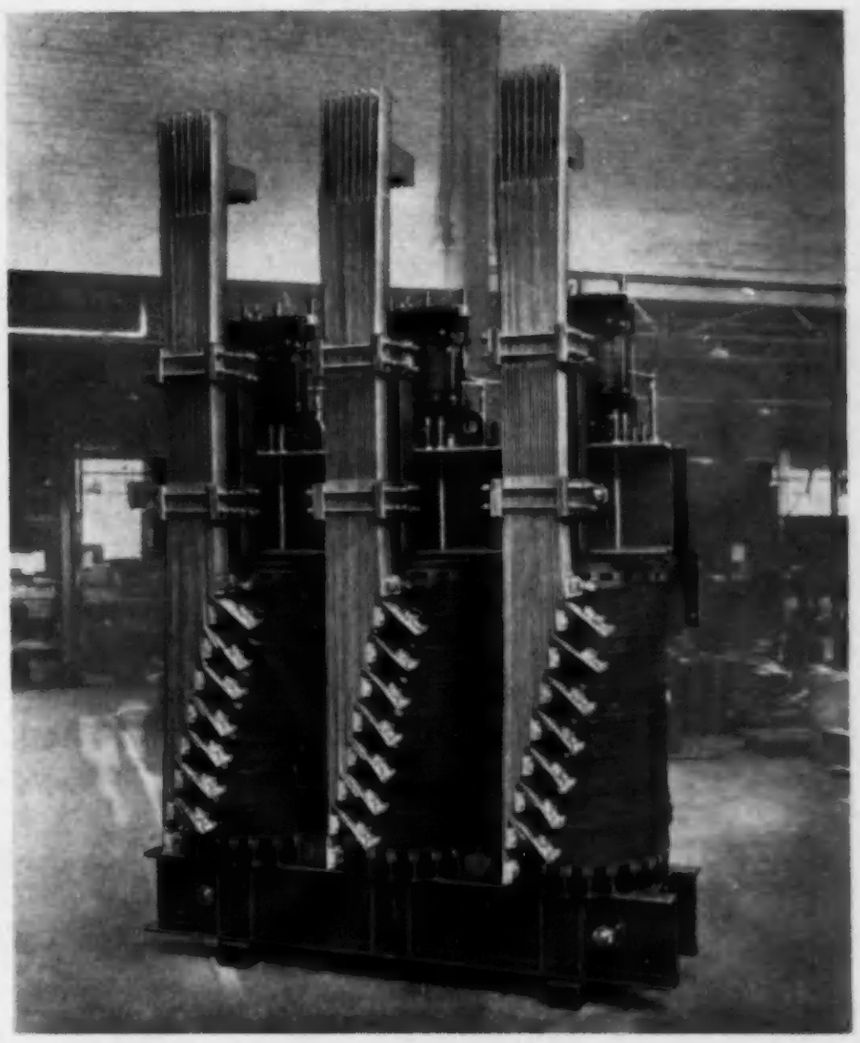


Fig. 33.—2,500 kVA 6,000/200 volt G.E.C. furnace transformer ; secondary current, 7,300 amps.

MOTOR PLURAL STARTER EQUIPMENT.

Motor plural starter equipment was originally developed in connection with marine work. A complete description of a marine equipment was given in the *G.E.C. Journal* (Vol. IV, No. 2, p. 124 *Q.T.E.V. Queen of Bermuda*). The same principles have now been applied to industrial work, and the illustration at fig. 32, shows an industrial type plural starter board at the Aylesford Paper Mills (Kent), of Albert E. Reed & Co., Ltd. Two sets of equipment are provided, one for twelve 340 h.p. motors, and the other for three change over panels which ensures that a spare starter is available. Owing to the large capacity of the motors, time controlled contactor equipment is employed.

Each motor panel carries positive and negative line contactors, a starting contactor, overload relays, a field relay and field regulator, also an isolating switch. Pressure of its associated "start" button causes the starting contactor and negative line

contactor to close, connecting the machine to the line via the whole of the starting resistance. At the same time the timing element of the starter is set in motion and the motor is accelerated up to speed. During this time all other push buttons are inoperative. At full speed the positive line contactor closes, the starting contactor opens, and the starter resets in readiness for the next operation.

THERMAL DIRECT-TO-LINE STARTERS.

A range of ironclad direct-to-line contactor starters with inverse time-element overload tripgear upon the thermal principle has recently been introduced. The method has numerous advantages over the older oil dash-pot arrangement, of which should be mentioned (1) the more consistent protection of the motor against over-heating, and (2) the absence of improper variation due to changing viscosity of the oil. Moreover, thermal behaviour of the protected winding is closely followed, and the starter cannot be burnt out by heavy overloads before tripping occurs. Adjustment is very simple, being accomplished by rotating a single calibrated disc, which varies the unlatching movement of bimetal strips in each phase. The trip-gear has hand-reset characteristics. Starters of this pattern (fig. 31) are at present made with eight capacities of overload element, ranging from 2 h.p. to 15 h.p., but further sizes are in course of development for motors below and above this range. The design has also been applied to star-delta starters.

TRANSFORMERS.

Amongst a large number of transformers built, three 2,500 kVA, 6,300/200 volt units with secondary current of 7,300 amperes should be referred to. One of them is to be seen in fig. 33. Accurate control of the L.T. voltage was necessary and to accomplish this an on-load tap changing switch was fitted on the H.V. side so that a constant outgoing voltage could be maintained. In addition, an off circuit switch giving four ranges of voltage was also fitted to the transformer. Fig. 33 shows the arrangement of the interleaving of the two outgoing leads on the secondary side of each phase.

The on load tapping switch shown in fig. 34, is for use with a 12,000 kVA, 33,000/11,000 volt transformer. The radiators for this unit were mounted in separate banks in accordance with the latest practice for this size of transformer.

Mention should also be made of the various rectifier transformers which have been made, while useful progress has been made in the design of distribution transformers, especially those required for pole mounting.

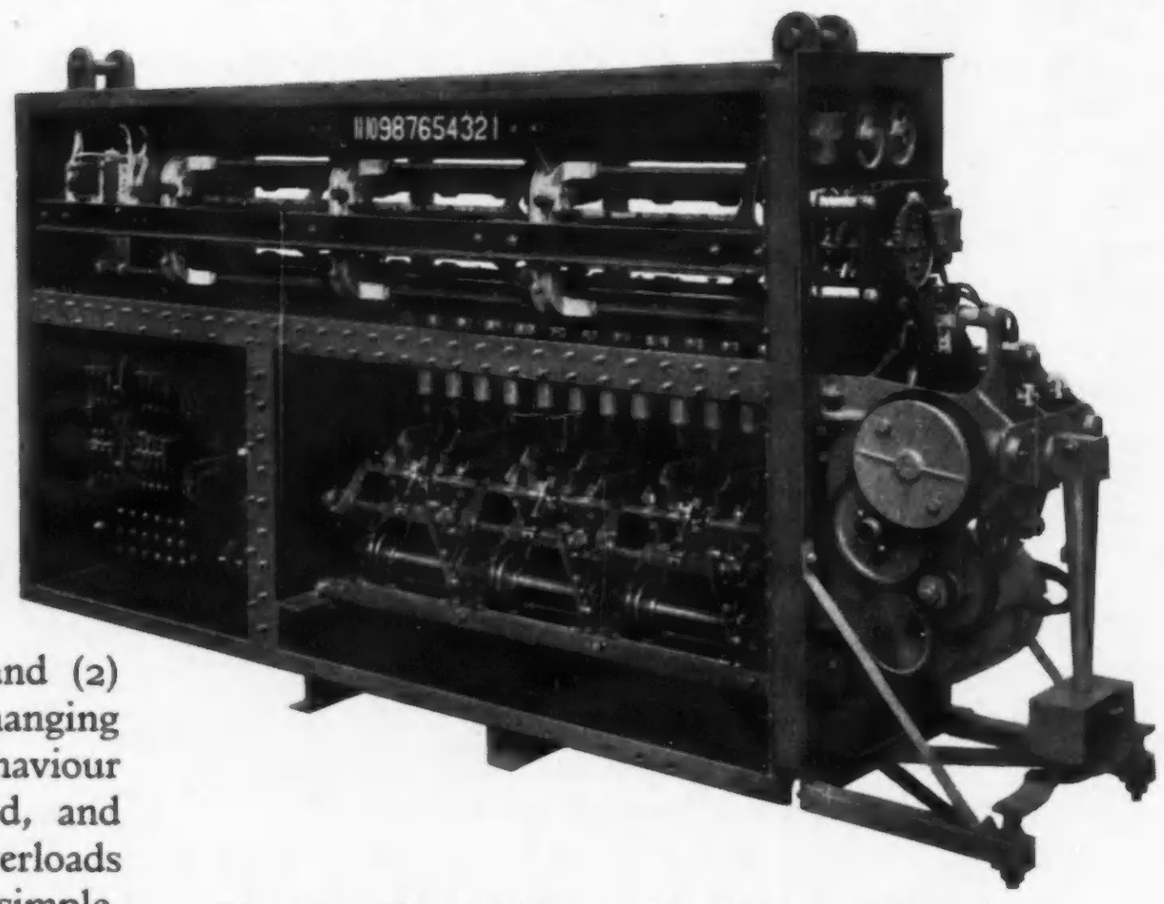


Fig. 34.—"On-load" tap changing equipment for transformers from 2,000 to 12,000 kVA.

STATIC CONDENSERS.

In view of the extent to which static condensers are being used for power factor correction, *e.g.*, A.C. motors, distribution lines, high frequency electric furnaces, etc., the section of the works devoted to their manufacture has been considerably extended and re-equipped with the most modern plant; a view of some of the new apparatus is shown in fig. 35. A complete investigation into the methods of condenser production has been undertaken in the

Fig. 35.—Part of the new equipment of the condenser shop at Witton.

Witton Development Dept., as a result of which great improvements have been made both in design and manufacture. The spools as now designed have a low power factor and minimum losses, while the highly efficient method of spool cooling employed ensures operation at a very low temperature. Tests have shown that the possibility of trouble due to surges has been considerably minimised. The condenser spools are mounted in hermetically sealed unit boxes, this process being carried out under an extremely high vacuum, the oil to be used having first been carefully dehydrated and degasified.

Fig. 36.—One of the fifty Leyland-G.E.C. six-wheel trolley buses supplied to Birmingham Corporation.

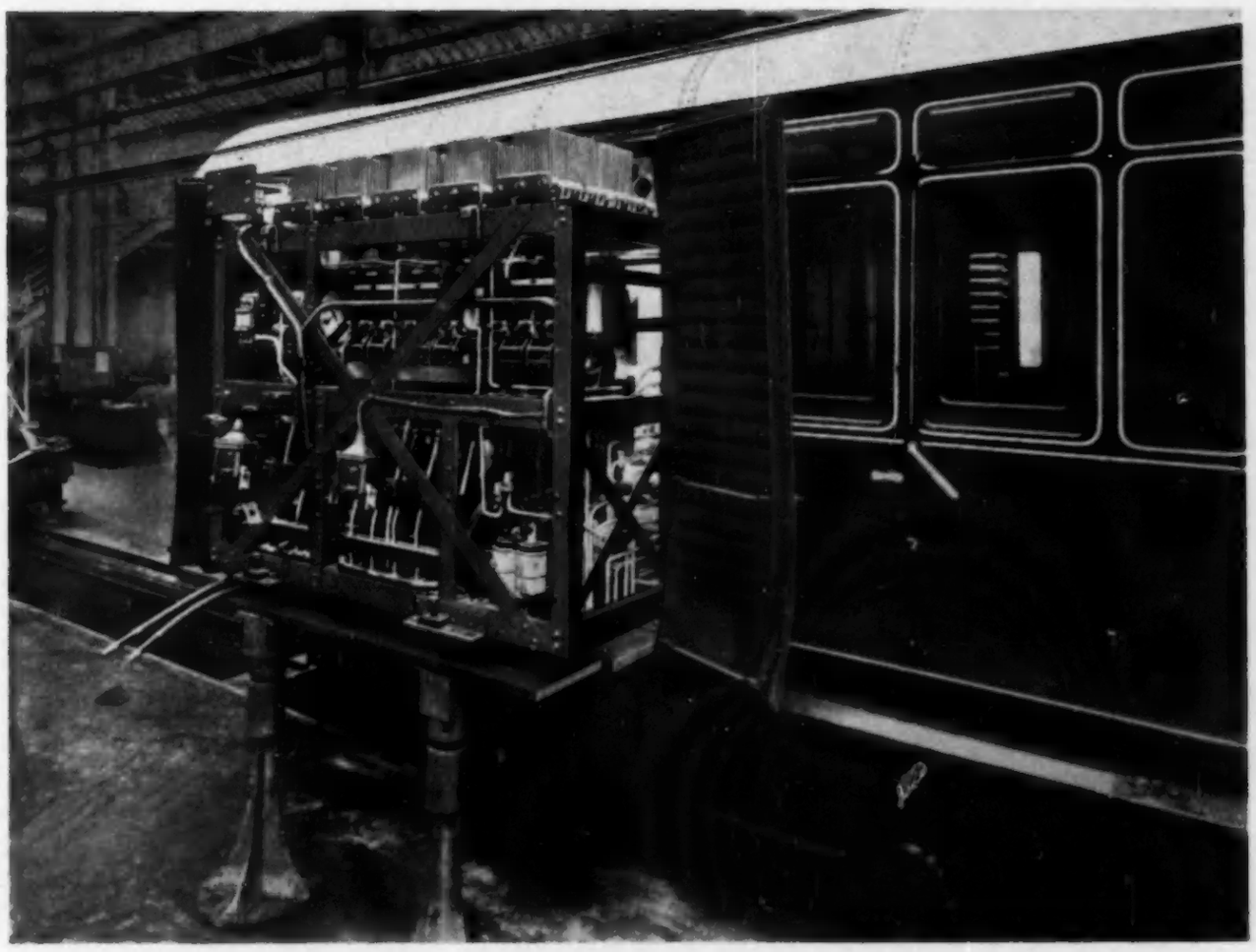


Fig. 37.—The control gear for the new L.M.S. electric rolling stock is mounted on a special framework which can be withdrawn bodily from the coach for maintenance work.

The unit system, *i.e.*, building up any required condenser kVA from standard boxes, offers great advantages, as the leading kVA can be reduced or increased at any time by the removal or addition of unit boxes. Every box is fused individually.

RAILWAY ELECTRIFICATION.

In spite of the industrial depression which has been felt acutely by the various railway companies, the past year has witnessed activity in railway electrification, as is evidenced by the production and placing in service of new electric rolling stock for the Metropolitan and the L. M. & S. Railway Companies.

The equipment for the Metropolitan Railway will be fully described in an early issue of the *G.E.C. Journal*. Briefly it comprises motors and control gear for eighteen motor coaches, fourteen driving trailer coaches, fourteen first-class and nineteen third class trailer coaches.

The coaches are of the compartment stock type and conform closely to main line practice as regards mechanical construction. Each motor coach is equipped with four axle-hung motors, hourly rated at 210 h.p. at 535 volts, the motors being geared to the wheels through a gear ratio of 1 to 3.1.

The power circuits, together with the associated control circuits, are arranged in two entirely separate groups, one group controlling motors 1 and 3 on a coach, and the other group controlling motors 2 and 4. In this way a high degree of service reliability is obtained, since either group may be isolated by a switch in an emergency. The control gear is operated electro-pneumatically and automatic acceleration is provided by means of which the train is automatically accelerated at a predetermined acceleration as soon as the driver operates his master controller.

As regards the equipment for the L. M. & S. Railway, a total of 8 motor coaches, 13 driving trailer coaches and 10 trailer coaches were placed

in service towards the end of the year on the Euston-Watford section of the line. The equipment supplied comprised the power and control apparatus ; also that for the lighting and heating of all the coaches.

In design and construction the mechanical portion of the coaches closely follows that of main line stock. On the electrical side each motor coach is provided with four 320 h.p. motors capable of giving a high acceleration. The motors are grouped in pairs, each pair being controlled by a set of all-electric control gear. Automatic acceleration is provided and is under the control of a current limit relay.

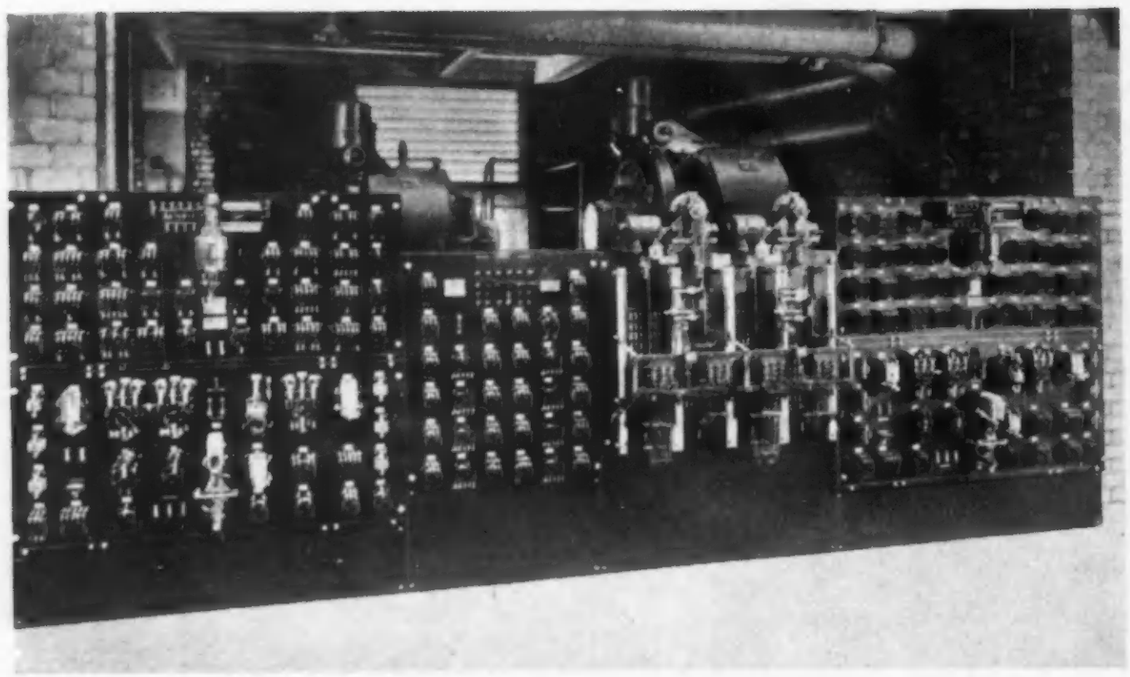


Fig. 38.—Control gear for two interconnected gearless lifts.

A feature of particular interest is the method adopted of mounting the control gear on a special framework which can be removed bodily from the coach for maintenance work (fig. 37). This arrangement materially reduces maintenance cost when the coaches are being overhauled.

A train unit is normally formed from three coaches, a motor coach, trailer coach and driving trailer coach. During rush hours two such train units are coupled together to form a six coach train.

TRAMWAY EQUIPMENT.

Developments in connection with tramway equipment include a new type of cam controller which embodies a number of new features giving a higher rupturing capacity and simplifying installation and maintenance. A number of these controllers have been supplied to prominent Corporation Tramway undertakings and have met with considerable success.

Two interesting experimental equipments have been made to the order of the London Passenger Transport Board. The first is a special weak field control equipment giving approximately 50 per cent field weakening. The two motors on the experimental car have the field coils arranged for a tapped-field control. Each motor is rated at 65 h.p. 525 volts and is constructed to give the maximum stability under the conditions encountered on the particular system they serve.

The second equipment is a regenerative one, consisting of two compound wound motors with the necessary control gear. The motors have the series and shunt ampere turns so balanced that the required performance is obtained under the most severe conditions of service.

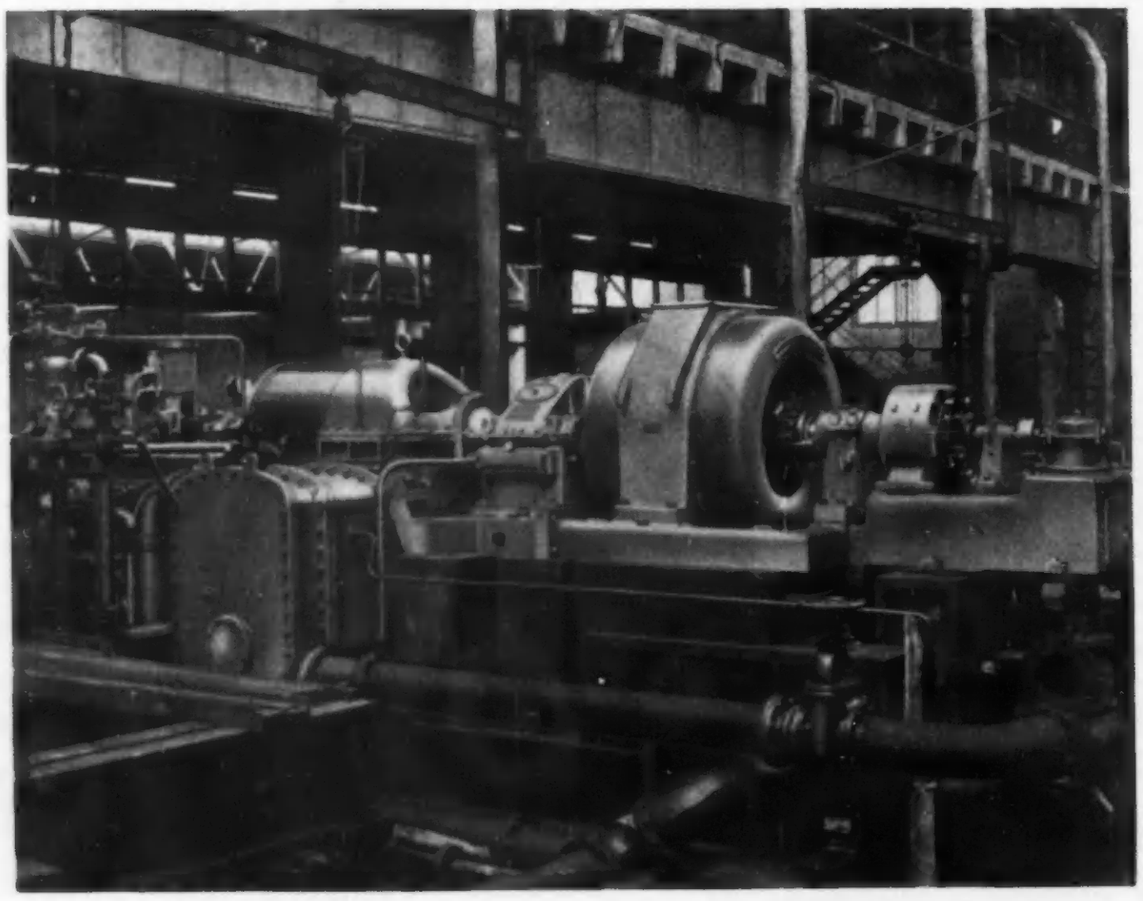


Fig. 39.—750 kW 7,000/1,500 r.p.m. G.E.C.-Fraser & Chalmers geared turbo-alternator with built-in condenser under test prior to shipment to China.

TROLLEY BUSES.

In the early part of the year, 14 trolley buses with G.E.C. electrical equipment were placed in commission for the Llanelly & District Electric Supply Co., Ltd. These were each driven by a single 80 h.p. motor having a considerable amount of field control. This was closely followed by the delivery of three single deck, six-wheel trolley buses for Perth, Australia. The electrical equipments for these buses were in most respects similar to those for Llanelly.

A very large order for trolley buses was recently received from the Birmingham Corporation ; it called for the manufacture of electrical equipment for 50 six-wheel double deck trolley buses. Each is equipped with a single 65 h.p. 500 volt motor and control gear.

MARINE ELECTRIFICATION.

The most important development of the year in connection with marine work was the completion of the Diesel-electric tug *Acklam Cross*. This is the first tug in Great Britain to be fitted with Diesel-electric propulsion equipment and is undoubtedly

the forerunner of many similar vessels. It is fully described on page 55 of this issue.

Following the success of the *Acklam Cross*, the contract was obtained for the complete electric propulsion equipment for a passenger boat for the Portree (Isle of Skye) service. This will be a twin-screw vessel, each propeller being individually driven by a 525 h.p. 400 r.p.m. D.C. motor supplied with power from a 425 kW 500 volt 500 r.p.m. Diesel-engine driven generator. The motors will be separately excited from a 48 kW, 230 volt, 500 r.p.m. generator coupled in tandem to each main generator. The vessel will be completed in 1934.

A further important development is the application of electric lighting to fishing trawlers. In the past, these vessels have been illuminated by means of carbide lamps which, apart from their disadvantages from an illuminating point of view, introduce a serious fire risk. Special equipment has now been designed and installed on one of the trawlers of a Scottish fishing fleet whereby electric lighting is obtained. The installation has been a noteworthy success and it is confidently expected that the practice of electrically floodlighting the decks of trawlers will become general practice.

Intimately connected with marine work is the electrical equipment for the William Froude testing tank at the National Physical Laboratory, which was described in *G.E.C. Journal* (Vol. IV, No. 1). It is of interest to note that there has now been added to the existing equipment further apparatus for propeller testing to be used in conjunction with the tank equipment. It comprises an 80 h.p. motor whose function is to drive an impeller which circulates water at varying speeds in a cast iron tunnel; also a 4 h.p. motor which drives the propeller under test. In both cases very fine speed adjustment is necessary. The 80 h.p. impeller motor is supplied through a negative booster for low speeds and is connected to the 440 volt line for higher speeds which are reached by shunt control. Special precautions are taken to ensure that the change-over from booster to line is effected without sudden speed change. The booster set is automatically shut down when the main motor is connected to the line and is automatically restarted when the main motor speed is again reduced. The booster starter, regulators, contactors and isolators, together with the necessary instruments are housed in a sheet steel cubicle.

ELECTRIC LIFTS.

One of the new items of lift equipment introduced in recent months is a gearless motor suitable for medium capacity high speed lifts.

Various new features were embodied in the lifts for the *Q.T.E.V. Queen of Bermuda* (*G.E.C. Journal*, Vol. IV, No. 2, p. 116). Of these should be mentioned the installation of variable voltage control for three passenger lifts, which system includes the provision of automatic levelling by means of the inducer system. The equipment has performed satisfactorily and marks a distinct advance from the point of view of marine work.

The most novel technical development has been the application of control systems operating at low voltage to effect the selection of direction and floor and to provide for slowing down and stopping fully automatic lifts at floor level. This has involved close co-operation with the Telephone Works at Coventry, and a number of installations have been completed and are operating in an entirely satisfactory manner.

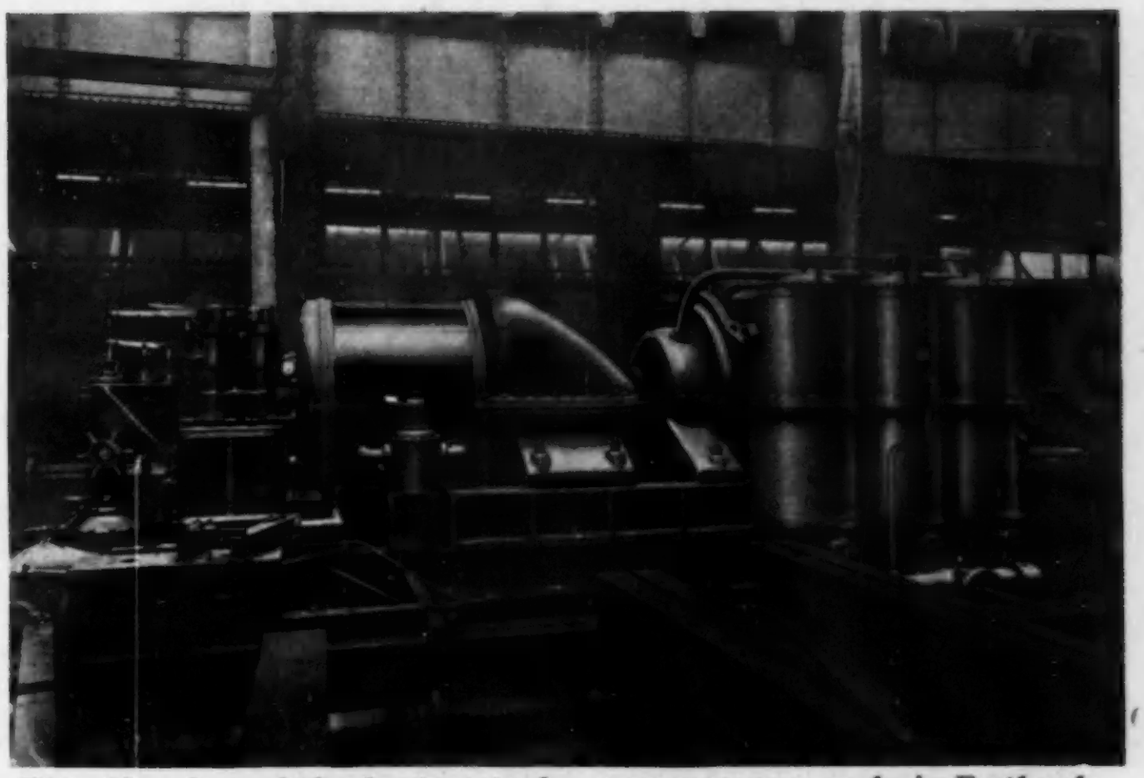


Fig. 40.—One of the largest turbo-compressors made in England; a single casing mixed pressure turbine driving a compressor capable of delivering 30,000 cu. ft. of free air per min. against a normal pressure of 85 lbs. per sq. in. This compressor has been made for the Randfontein Mines.

Works tests have just been completed on an equipment designed to give accurate floor levelling in conjunction with a single speed slipring motor for geared lifts for medium speed. The basis of this work was the application of a small motor generator set with suitable compound windings to give a slow speed to the lift of suitable negative slip, the worm shaft being coupled to a D.C. motor specially designed for this slow speed duty, in addition to the main slipring motor. The equipment has passed test requirements in the test tower at Northampton Works and is now in service. This equipment also includes the low voltage control previously referred to.

AGRICULTURE.

Steady advance has been made during the past twelve months in the uses of electricity in agriculture and horticulture, but it is only possible to refer to a few of the most interesting developments here.

A notable departure from previous practice has been adopted for sterilizing dairy utensils and milk bottles for the production of high grade milk. For this purpose several chests have been supplied in which immersion heaters are incorporated in a separate compartment, in which steam is raised. Compared with other means of sterilizing, these chests have many advantages, as separate boilers and labour for handling fuel and ashes are entirely eliminated.

Progress has been made with the Magnet electric soil heating cable which is now manufactured in various lengths. The short lengths now available enable small garden frames to be heated; also they provide means for obtaining a small hotbed. Supplementary bottom heat can be provided in commercial greenhouses for expediting the growth of tomatoes and similar crops.

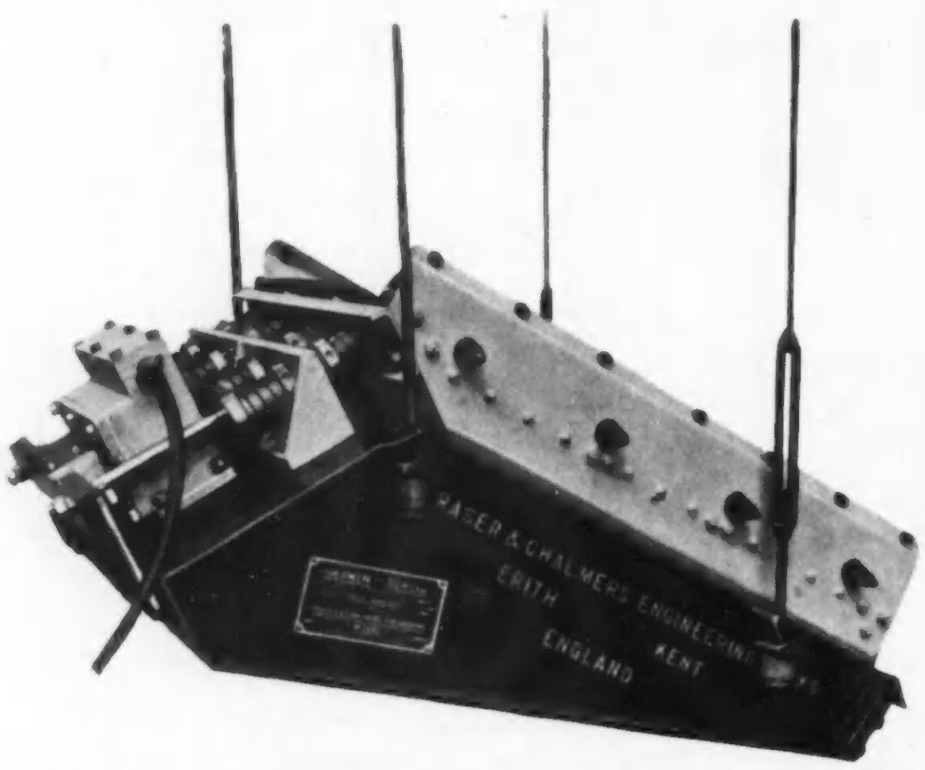


Fig. 41.—The new Sherwen A.C. electro-magnetically vibrated screen.

In the poultry industry an important development is the great increase in the use of cabinet incubators which are now made in sizes to hold from a few hundred eggs up to several thousands. Electricity is used not only for heating, but also for driving fans for circulating the air.

A special study has been made of the electrical equipment for the leading makes of incubators, and motors and heating and temperature control equipment are being supplied for several types of incubator.

STEAM TURBINES.

Reference was made earlier under the heading "Generating Plant" to turbine driven electrical plant. A type of geared turbine which offers many advantages from the point of view of reducing foundations to a minimum is shown in fig. 39. The condenser is arranged at the side of the turbine with its axis at right angles to that of the turbine. This layout is being increasingly adopted.

One of the largest turbo-compressors made in this country (fig. 40) has just been shipped to South Africa. It is a single casing mixed pressure machine, the unit being capable of delivering a normal quantity of 30,000 cu. ft. of free air per minute against a normal pressure of 85 lbs. per sq. in. gauge. The set is for the Randfontein Mines and is the second compressor of this capacity for that undertaking.

Two other machines now being built at Erith are of interest. They are high pressure steam turbo-blowers for the new Corby Works of Stewart & Lloyds. Each of these units is capable of delivering a normal quantity of 44,000 cu. ft. of free air per minute against a pressure of 20 lbs. per sq. inch gauge.

PULVERISED FUEL.

Amongst the pulverised fuel plants started up during the year is the installation at the Newmarket Colliery, Wakefield, Yorkshire. This installation comprises four new 30 × 9 Lancashire boilers of the Spurr Inman type, having a steam pressure of 80 lbs. per sq. in., and a normal rating of 9,000 lbs. of steam per hour (actual), the feed entering the boilers being 140° F. Each boiler is fitted with two Fraser & Chalmers low velocity Lancashire boiler type burners.

HEAVY OIL ENGINES.

Several heavy oil engines have been built during the year. Two of these were for the Haverfordwest Station of the West Cambrian Power Co. One is a 6-cylinder engine of 1,700 b.h.p. capacity, the other being a 3-cylinder unit of 840 b.h.p. Both drive alternators built in Witton Engineering Works.

A 1,650 b.h.p. six-cylinder engine for the Macao Electric Supply Co. was recently put into commission, while a further engine of the same size has since been ordered by this company. These engines, also, drive G.E.C. alternators.

It should be added that various power stations in which Fraser & Chalmers oil engines are installed continue to maintain records for low fuel consumption, as recorded in reports of the Diesel Engine Users' Association.

MATERIALS HANDLING PLANT.

Increased activity in road construction and repair has been responsible for the supply of a number of slag handling and conveying plants in various parts of the country.

Coal breakage at docks is still a matter of concern both to the shipping companies and coal merchants. Research and experimental work is continuing with a view to producing more efficient anti-breakage loading devices. A newly designed plant is at present undergoing actual tests at a docks, and the results are very encouraging.

Plant for an installation of novel character is now in process of manufacture. It is for the conveying, blending, storing and sifting of tea in a large factory in the Midlands. This plant comprises Fraser & Chalmers Redler conveyors and elevators, blending and storage bins, sifters, connecting chutes, etc., and will handle 10,000 lbs. of tea per hour, provision being made for increasing this capacity to 15,000 lbs. in the future. The whole of the plant is electrically operated, the automatic blending being particularly ingenious.

DUST SEPARATION.

A considerable amount of research work into the question of dust nuisance has been carried out at Erith resulting in the development of a new dust separator which covers a very wide range of application. This separator, the "Cheltnam" Micron Dust Separator, has recently been tried out on various classes of dust, efficiencies as high as 98 per cent having been obtained, which is much in excess of figures previously obtained.

The "Micron" separator differs in important essentials from other types of mechanical separators, and in particular, provision is made to avoid "entraining" action which is a serious drawback in some types of separator. The term "entraining" is used to describe the action by which dust already extracted from the air might be again introduced into the path of the clean air.

MINING.

Renewed activity in mining undertakings has resulted in a greater demand for mining machinery of every description; particular reference in this connection should be made to the new goldfields of Kenya and Tanganyika.

The electric winder shown in the frontispiece to this issue is for an Indian Gold Mine. The weight of ore per wind is 5,300 lbs., the vertical lift is 3,633 feet, and the speed of wind 1,910 feet per minute. The electric motor is a geared direct current machine of 1,150 h.p. capacity.

Complete mining equipments handled during the year include a diamond ore dressing plant for S.E. Borneo, and a sulphur plant for Palestine.

Much experimental work has been carried out with a view to improving the design of vibrating screens both of the mechanically vibrated and the electro-magnetically vibrated types. The most recent addition to the range of Fraser & Chalmers screens is the A.C. Sherwen electro-magnetically vibrated screen illustrated at fig. 41. The success of this screen is due to the extreme simplicity of its operation, combined with high efficiency. The contact gear used on the D.C. type of Sherwen screen is eliminated, and the vibrations are obtained by the use of a half-wave rectifier connected in series with the vibrator coils. The cycle of operations begins with the rectified half-wave from the rectifier passing to the vibrator coils and drawing forward the armature which is connected to the screen frame. During the other half-wave of the A.C. cycle, the current is prevented from passing to the coils, thus enabling the springs supporting the armature and live screen frame to accomplish the return stroke. A 50 cycle A.C. supply transmits to the live screen frame an intense vibration of 3,000 cycles per minute.

UNIFORMITY IN LAMP PERFORMANCE.

Further steps have been taken towards the attainment of complete uniformity of lamp performance, as a result of which the limits

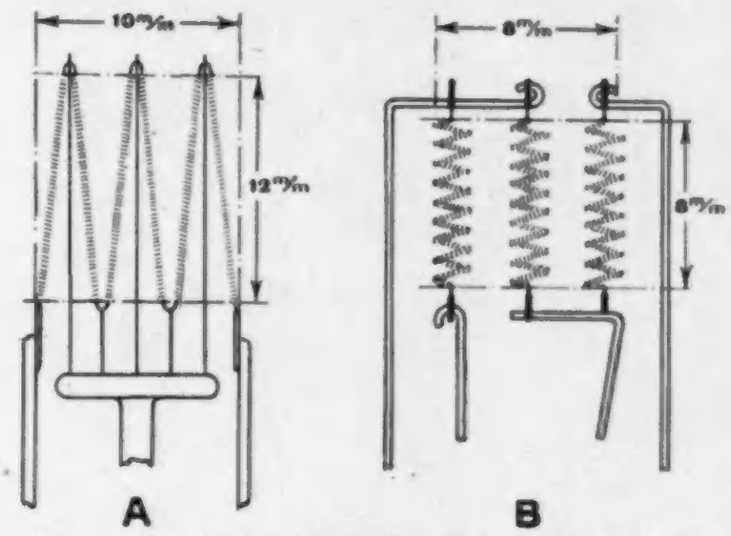


Fig. 42.—(A) Illustrating the old coiled filament. (B) The new coiled-coil formation.

of variation in one lamp from another have been considerably narrowed down. A further equally important type of uniformity is desirable, namely, uniformity of light output throughout the life of each lamp. It should be observed that the best lamp is not necessarily the one which gives the greatest number of lumen-hours light since this can be obtained by lamps with an exceptionally high initial efficiency which, however, falls towards the end of the life of the lamp by 20 per cent or more. The ideal lamp is that which gives practically the same light at the end of its life as at the beginning; this object has been attained with complete success.

LAMPS FOR SPECIAL PURPOSES.

A number of improvements in the design of existing types of special lamps has been effected and new types of lamp have been developed, more particularly for meeting the requirements of new apparatus. For instance a 4 volt 24 watt lamp with Edison screw cap has been introduced to fulfil the requirements of the new Gaumont sound film recording apparatus. Another range of lamps designed for use as projector lamps furnishes a further case in point. The new range includes a 50 volt 200 watt tubular lamp with prefocus cap and offset filament for use in the British Acoustic 16 m/m film "Home Talkie" equipment; a 3,000 watt lamp in a small 200 m/m diameter bulb with a flat "grid"

filament in place of the former bunch filament, and a 5,000 watt general lighting service cinema studio lamp with a bunch filament.

An important improvement in these lamps relates to the length of the lamp filament which is prescribed by the voltage and wattage of the lamp. The problem involved in securing the small light source necessary for projection work is to mount a comparatively long length of wire within a sufficiently small area. The invention of the spiralised filament originally made projector lamps a practical proposition, and subsequently the introduction of tempered filaments enabled the filament areas to be reduced very considerably.

Within the last twelve months, still further improvement in filament technique has made possible a new coiled-coil type of filament which as the name implies consists of a spiralised filament which is again wound in a spiral and set in this form by a special heat treatment. As a result the filament area is almost halved; for instance, the filament area of a 110 volt 250 watt class A.1 projector lamp which was formerly 120 sq. m/m has now been reduced to 64 sq. m/m. This process, for which The General Electric Co. Ltd., holds patents, is gradually being applied to the filaments of all the grid filament Osram projector lamps.

A new method of filament mounting is also employed known as the "gantry" construction. The filament is welded in the form of a series of short straight coils across a rigid framework which ensures accurate positioning and eliminates all possibility of the filament being knocked out of position by rough handling. The lead and support wires are kept out of the line of light projected from reflectors mounted behind the lamp. Briefly the new coiled-coil filaments have resulted in a lamp which is stronger and gives more useful light, *i.e.*, increased screen illumination.

A range of tubular lamps 500 m/m long and 30 m/m diameter in straight and curved lengths has been developed in a wide variety of colours for modern architectural lighting. They are made on the same principle as Osram Striplite lamps but to cope with the extra length a new method of mounting the filaments has been devised, while the caps instead of being on the ends of the lamps are

Fig. 43.—Centre Court of the Cumberland Hotel showing the concealed cornice lighting using Claudegen Sunlight tubes and decorative lighting.

Fig. 44.—Lighting at Piccadilly Station on the Underground Railway.

mounted on the sides so that lamps may be placed end to end to form a continuous band of light, or built up otherwise into attractive patterns.

A single cap opal tubular lamp 302 m/m long and 38 m/m in diameter is another form of tubular light source now available. It is made in plain white opal or tinted either pink or amber.

Inside colour sprayed lamps which were introduced first in the 15 watt sign type bulb are now made in a 40 watt size as it was found that for large signs and many decorative lighting schemes more light was required than that given by the 15 watt lamp. The colours have been improved, especially as regards the evenness with which they are sprayed inside the bulb.

To extend the decorative value of the 14 volt 7 watt coloured olive shape decoration lamps a completely new range of decoration units has been produced. They are made of gilded asbestos papier-mache and provide a novel and striking means of introducing bright patches of colour into festive lighting.

The scope for Osglim neon discharge lamps has widened considerably during the past year necessitating their production in many different sizes and shapes ranging from tubular lamps about $\frac{1}{4}$" in. diameter to the indicator lamps used on electric cookers. The type, however, which will eventually be in greatest demand is a small lamp $\frac{1}{2}$" in diameter taking 1/5 of a watt, made for incorporation in lamp switches which may thereby be located easily in the dark.

Fig. 45.—The Royal Society of Arts, Burlington House, lighted indirectly by mirror glass reflectors fitted into bronze bowls.

PHOTOGRAPHIC LAMPS.

The success of the 500 watt high efficiency photographic lamp, which was introduced in 1932, has led to the introduction of a smaller lamp with a standard bayonet cap to enable amateurs to take photographs in any room without requiring any special apparatus. They are called Pearl Osram photo-flood lamps and take 200 watts, giving a light which is $3\frac{1}{2}$ times more actinic than that of an ordinary 200 watt lamp.

"Sashalite" photo flash bulbs although not electric lamps in the strict sense of the word owe their existence to experience gained in electric lamp manufacture, and their production is of such benefit to all engaged in photography that a survey of the year's progress in lamp development would not be complete without reference to them. "Sashalite" bulbs are clear glass bulbs of the shape of an ordinary electric house lamp fitted with a cap and with a pinch carrying two leading in wires on which is mounted a fine filament coated with a priming composition. The bulb contains a definite quantity of extremely thin aluminium foil and is filled with oxygen at a low pressure (about 1/5 of an atmosphere). The bulbs are made in two sizes, known respectively as the standard "Sashalite" and baby "Sashalite." The latter has been introduced to enable amateurs to enter the field of flashlight photography. Both sizes are made for operation with an electric torch; they must never be connected to house lighting mains.

By operating the switch of the torch sufficient current passes to heat the filament in the bulb and ignite the primer. This causes the foil to burn with extreme rapidity giving an intensely brilliant flash which lasts approximately 1/75 sec., the light output being of the order of 45,000 lumen seconds. All smoke and residue remain enclosed within the bulb.

The speed at which the "Sashalite" bulb operates enables exposures to be made far more readily than is the case where flash powder is used. Besides eliminating danger from fire indoors, the bulbs can be used outdoors in circumstances which would render impossible the use of flash powder.

DECORATIVE ILLUMINATION.

In reviewing electrical progress during 1932 (*G.E.C. Journal*, Vol. IV, No.1) attention was drawn to the tendency among architects to incorporate lighting features as an integral part of decorative schemes either built into, or super-imposed upon, the structure. This tendency has definitely advanced during 1933 and has presented an entirely new problem to the illumination designer.

In the past, decorative lighting units of a self-contained nature have been employed and it has been possible, by means of photographic and pictorial representation, to give the architect or

purchaser a very fair idea both of the decorative and illumination effects which will be obtained. But where decorative illumination is built-in as part of the structure, and perhaps embodies a proportion of indirect or semi-indirect lighting, while the line and form of decorative treatment embodied in the scheme may be shown by drawings, it is quite impossible to give an indication of the resultant lighting effect.

Fig. 46.—The new "Osira" lamps installed along Great Portwood Street, Stockport.

To cope with this situation, an entirely new showroom has been equipped at Magnet House, Kingsway, where lighting features of this nature are displayed so that both the decoration and illumination aspects of various methods of lighting may be inspected.

Particular attention in designing such units has to be paid to the interior arrangement so as to obtain the maximum light value under the particular system concerned and, at the same time, to facilitate maintenance. To arrive at these results close co-operation between building contractors, decorative designers, and illuminating engineers must be maintained at every point.

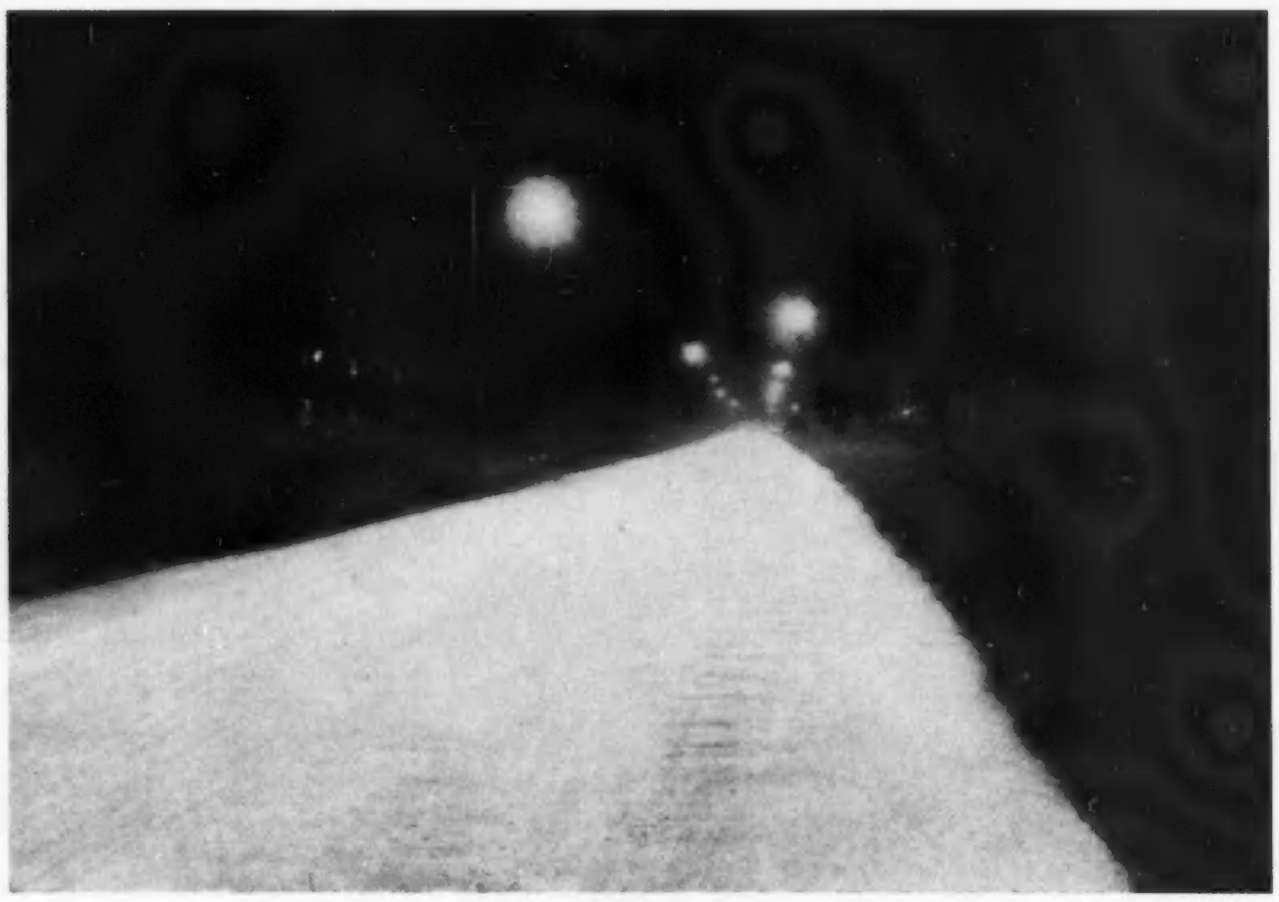


Fig. 47.—An arterial road at Manchester illuminated by the new "Osira" lamps.

A change-over in technical illumination glassware from foreign to British manufacture was reported in *G.E.C. Journal*, Vol. IV. No. 1, p. 26. It was also indicated that a similar change-over was beginning to take place in decorative glassware. This further change-over has now materialised so that practically all the glass used by the G.E.C. in its decorative fittings is of British manufacture. In flashed opal glassware, colour tints have been obtained which represent a distinct advance, while the overall efficiency of opal glass diffusing units has been increased.

Amongst the outstanding decorative lighting installations completed during the year is that at the Cumberland Hotel (fig. 43) and Marble Arch Corner House recently completed for J. Lyons & Co. Ltd. Mention must also be made of the completion of the lighting at the stations on the Cockfosters extension of the London Electric Railway, and the re-equipment of such stations as Hyde Park Corner and Marble Arch. A wide variety of methods of lighting has been adopted in these various stations ranging from indirect units placed above the booking hall kiosks to the continuous lines of moulded glass ceiling trough employed at the two stations last mentioned.

In addition to the work carried out on decorative fittings for special purposes, the range of stock lighting fittings has been considerably added to by the manufacture of a number of decorative pendants, wall brackets and ceiling fittings on modern lines, which are simple and dignified as well as attractive in appearance. Full use has been made of the wider range of British decorative glasses and of the new types of lamps available, such as the architectural Striplite and the single-ended tubular lamps. An up-to-date chromium plating equipment

has been laid down at the works and has been extensively used in the production of such fittings.

Further progress has been made in the design of indirect lighting fittings embodying the P.L.A. silvered glass reflector and sixty-six units of this nature were used to illuminate the Conference Room at the Geological Museum during the 1933 World Economic Conference, whilst similar reflectors in various housings have been used in a number of the new Underground Stations for illuminating booking halls (fig. 44).

Another installation of outstanding interest is the complete equipment of both the new section and old building of the Walker Art Gallery, Liverpool with G.E.C. art gallery fittings of a type specially designed for the National Gallery.

HOSPITAL FITTINGS AND EQUIPMENT.

The standard hospital operating theatre fitting has been re-designed with an improved system of counter-weight suspension and a permanent emergency lighting equipment has been embodied. These fittings have been supplied to several hospitals under the control of the War Office, Admiralty, Air Ministry and the London County Council.

Fig. 48.—Cockfosters station depot yard. This is not a day-light picture, but one taken at night by G.E.C. flood-lighting.

STREET LIGHTING.

The outstanding development in street lighting has been the practical application to the lighting of public thoroughfares of the new "Osira" lamp which was first utilised for the lighting of an important public thoroughfare as far back as June 1932, when it was employed under normal operating conditions for the lighting of East Lane, Wembley. This installation, the first in the world to utilise the new light source, proved so successful that in March 1933, it was followed by the larger and more widely known installation a mile and a quarter in length along the Watford Road, Wembley, which has been operated nightly without interruption since its inauguration and has attracted world-wide attention. Since that time further installations have been erected at Belfast, Birmingham, Blackpool, Bridlington, Croydon, Kingsbury, Lewisham, Manchester (fig. 47), Oldham, Rochdale, Kingston-on-Thames and Stockport (fig. 46), whilst in many other parts of the country installations are in course of erection.

Fig. 49.—Torquay Town Hall is floodlighted in two colours by means of "Osira" colour floodlights.

The radical change in the method of light production introduced by the advent of the new lamp rendered desirable the development of an equally radical change in the technique of light control. To enable the very high luminous output of the new source to be utilised to the full, a series of special lanterns has been designed for street lighting, to which reference has already been made in the section of this article outlining work undertaken in the Wembley Research Laboratories (p. 7). These lanterns utilise the new shape and size of the light source to give the most effective distribution of light on the surface of the roadway. Typical examples are illustrated by the photographs reproduced in figs. 3, 4 and 5, from which it will be apparent that the new lanterns constitute a

departure from conventional design as radical as the change in the method of light production. Moreover they combine a handsome appearance with a light distribution specially suited to street lighting requirements. Their efficiency is of a high order.

The use of the totally enclosed non-ventilated standard "Wembley" lantern, employing a gasfilled filament lamp has been steadily extended. An example of its adoption is furnished by the Borough of Finsbury, where over 700 gas lamps are being converted to electricity. The new lighting is now in operation in many of the more important thoroughfares in the Borough.

The range of the new reflector lighting units, the initial types of which were introduced towards the close of 1932, has been considerably extended by the introduction of special patterns for use in positions calling for a light distribution differing from the normal such as, for instance, at street intersections.

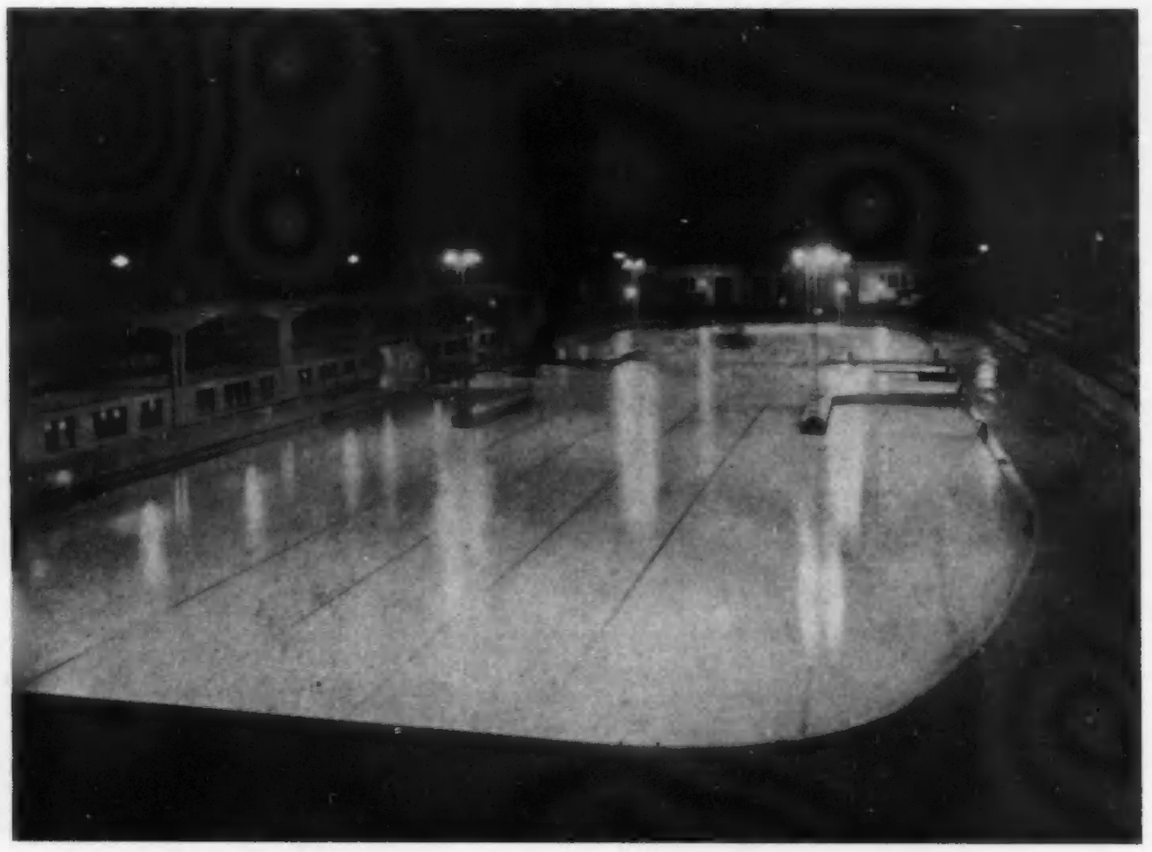


Fig. 51.—Hastings open-air swimming pool. Illumination underwater by floodlights and overhead by Wembley Lanterns.

"OSIRA" COLOUR FLOODLIGHTING.

The introduction of the "Osira" colour floodlighting lamp has opened up vast possibilities.

For use with these lamps a special housing has been designed, the main feature of which is a mirror glass trough reflector of a scientifically designed contour to make the maximum use of the new shape of the light source. With the aid of this reflector the light can be spread evenly over wide areas of building faces, or ground, from a comparatively small offset. This makes the floodlight peculiarly suitable for illuminating buildings of the simple design associated with modern architecture.

In the past, colour floodlighting has been ruled out in many cases on account of the heavy running cost, hence the economic value attaching to the very much higher efficiency of the "Osira" colour floodlighting lamp. This is particularly the case with red brick buildings which in the past have responded very badly to floodlighting in white light, but when floodlighted with red "Osira" lamps a rich warm glow is produced. Of the other colours available, the light green and blue are of such a soft tone that they can be effectively used on old stone buildings, such as churches, castles, monuments, etc., without any effect of garishness or loss of dignity such as might be associated with colour floodlighting by the old method.

Fig. 50.—Eton College illuminated by floodlights on the occasion of Dr. Alington's farewell to the school.

These floodlights have already been utilised in numerous installations all over the country, and over one hundred of them were employed in connection with the famous "Illuminations" at Blackpool. Other interesting installations include the lighting of the castle background at the Aldershot Tattoo, the floodlighting of Torquay Town Hall, originally done as a temporary installation during the E.C.A. Convention and since made permanent, and the floodlighting of gardens at Southend.

In industrial lighting also the "Osira" lamp as used for street light-

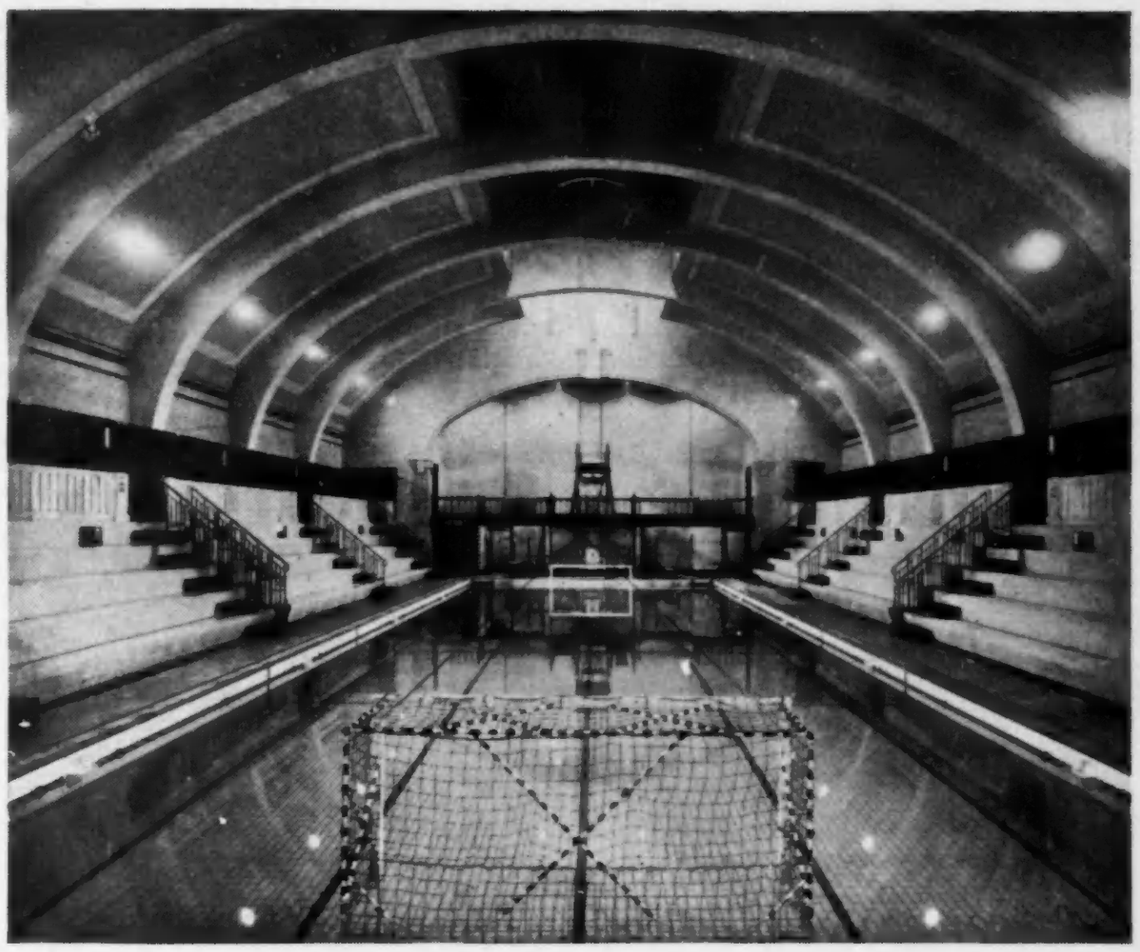


Fig. 52.—Indoor swimming baths at Kent Street, Birmingham, showing an installation of flush-mounted Gecoray floodlights equipped with 500 watt Osram lamps.

ing has shown possibilities of opening up new fields in the future, although for the present certain disabilities have imposed definite limitations. Successful installations have, however, been carried out in such situations as a foundry, a steel tube works, and a steelworks.

GENERAL FLOODLIGHTING.

The floodlights specially designed for railway yard work have been improved by the addition of an optical focussing device, which enables far quicker and more accurate focussing to be carried out under all circumstances. In practice it has proved possible for an operator to train and focus twenty floodlights fitted with this device in the time previously occupied in completing eight. The increased accuracy of focussing has resulted in an overall increase of illumination on the area covered, of approximately 50 per cent relative to the wattage consumed. Approximately fifty of these floodlights have been supplied to The London Electric Railway for the illumination of Cockfosters Yard, illustrated in fig. 48.

Other floodlighting installations of interest include Derry & Toms' new building in Kensington, Selfridge's new building off Oxford Street, and Leeds City Hall, while interesting temporary installations include the three-colour floodlighting of the Greenwich Pageant, and the lighting on a system of dimmer control of the Quadrangle of Eton College on the occasion of the late Headmaster's farewell to the School.

Floodlighting units have also played a prominent part in the illumination of outdoor and indoor baths, both for overhead and underwater lighting. In the latter category, the new baths at Hastings, illustrated in fig. 51, is a typical example, the underwater illumination being carried out with 500 watt floodlight units, while the overhead illumination is by means of "Wembley" lanterns. Of indoor baths that at Kent Street, Birmingham (fig. 52), shows a typical floodlighting installation in which the effects are obtained by means of a special system of floodlight reflectors set flush into the roof over the main baths.

Night sports have provided a further field for floodlighting, and installations have been carried out on numerous badminton courts, squash racquets courts, bowling greens, miniature putting greens and indoor tennis courts, while the lighting of dog tracks has again proved a market for the special G.E.C. reflector designed for this purpose. In this connection the most interesting installation of the year is that at the Stamford Bridge Track, for which, in addition to the specially designed "Dog Track" reflectors, an entirely new type of pole was provided. It allows the reflectors to be lowered on a level with, and alongside, the fence surrounding the track, so that when the centre of the ground is used by day for other sports, the poles do not interfere with the clear view of the spectators.

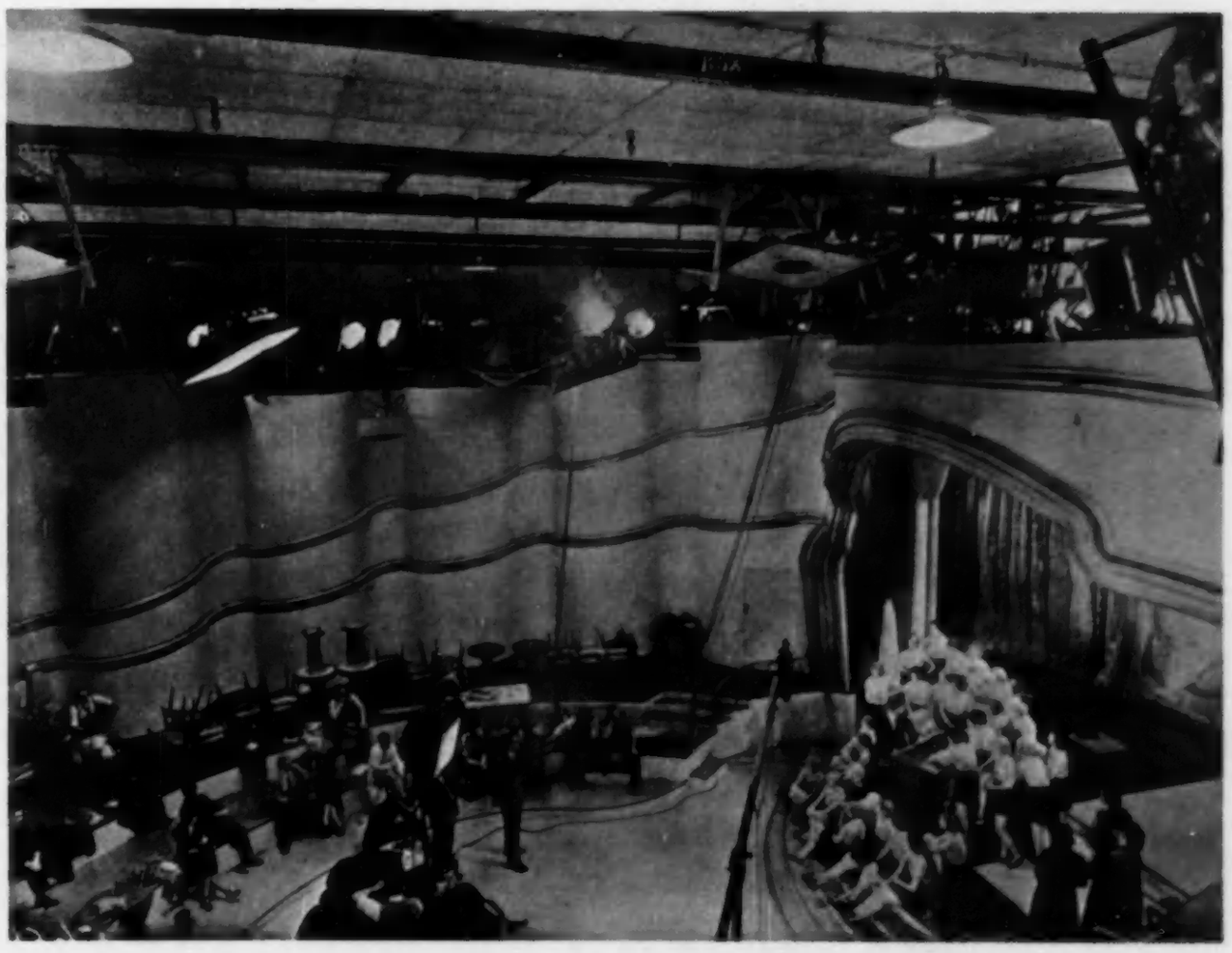


Fig. 53.—Filming a set at the Gaumont-British Studios equipped with G.E.C. studio lighting equipment.

CINEMA STUDIO LIGHTING.

A new 12″ diameter 2kW studio projector has been produced, which is one of the smallest mirror type 2 kW projectors available. By way of contrast

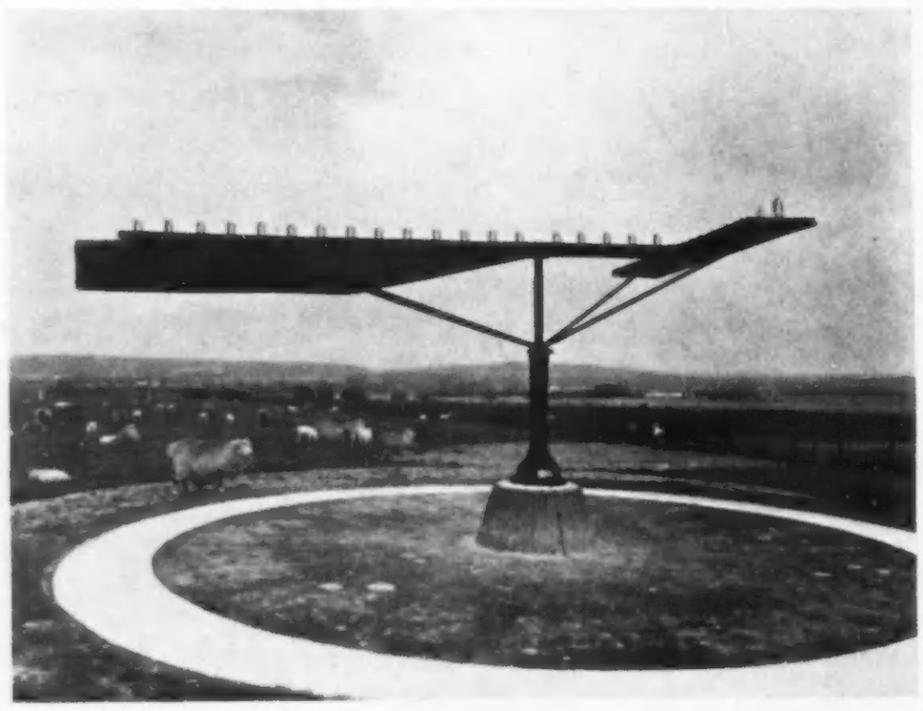


Fig. 54.—Aerodrome wind tee illuminated by electric lamps indicating to pilots at night the direction of the ground wind.

there has also been produced a 36″ diameter 10 kW projector, designed to carry out the work hitherto performed by Army searchlights at the Aldershot Tattoo. One of these fittings was supplied to the Aldershot Tattoo authorities for this year's event,

Fig. 55.—An effective scheme of neon lighting in three colours at the Olympia Radio Exhibition.

and its performance was extremely successful. The possibilities of such a unit for certain classes of film are obviously considerable.

The new Gaumont-British Studios have been equipped with projectors, broadsides, and overhead lighting units (fig. 53), this equipment having been responsible for the lighting of many of the principal British films released during the year, such as "I Was a Spy," "Britannia of Billingsgate," "Falling for You," and many others. Studio lighting equipment of various types has also been supplied for a number of cinema studios in India.

AERODROME LIGHTING.

More and more equipment is being required for the lighting of aerodromes and airways for night flying. After a series of experiments, designs have been drawn up for a special form of prismatic boundary light for use round the landing area and for a 1,000,000 candle-power single-flash airway beacon.

A 9 kW aerodrome landing floodlight has been in continuous use at Croydon during the last year. Improvements in the design and manufacture of the mirror glass reflectors used in this floodlight have improved the optical efficiency by approximately 100 per cent since this unit was first introduced in 1931.

Complete aerodrome equipments, including landing, floodlights, boundary lights and wind direction and speed indicators have also been supplied to China, Egypt and other Overseas Aerodromes, while a number of Neon Beacons have been supplied for use at aerodromes in this country.

LUMINOUS TUBING.

Another aspect of illumination in which marked progress has been made is in the development of luminous tubing as manufactured by Claude-General Neon Lights, Ltd., an associated enterprise of the G.E.C.

Tests with Claudegen artificial "daylight" tubes have been carried out on such varying materials as tiles, paper, Portland cement, leather cloth, silks, textiles, leather, etc., and have shown in every case that this form of light approximates to the ideal, not only for showing colour variations, but also for detecting blemishes in the texture or manufacture of materials.

An overhead installation has been carried out at the works of a company manufacturing leather cloth, while portable units have been supplied for use in several of the industries mentioned above. The advantage of this system of lighting, apart from its close approximation to daylight, is that throughout the life of the tube the colour value of the light remains absolutely constant, which is impossible of achievement in any system of corrected light depending on incandescent lamps, owing to the changes involved by ageing, voltage variations, etc.

The use of "Sunlight" tubing as a means of interior decoration has also progressed during the year, this system having been adopted for the main illumination of a section of Lyons new Corner House, as well as in the Centre Court of the Cumberland Hotel (fig. 43).

This form of lighting has also been used for external display, for which purpose it offers an effective and dignified contrast to the more familiar types of Neon lighting. Prominent installations embodying "Sunlight" tubing include the side illumination of the Luxor Cinema at Eastbourne, while the outlining of Magnet House, Kingsway, is a typical example of the very dignified effect that can be obtained. This type of lighting also lends itself peculiarly to the illumination of canopies, a typical example being the Gaumont Palace at Lewisham.

NEON LIGHTING.

It is significant that architects are displaying growing interest in the use of "Neon" signs. A majority of members of that profession engaged in commercial work appreciate that every commercial building is likely to have recourse to Neon displays. They have, accordingly, considered these as an integral part of the design, and produced some exceedingly fine examples of the art. Two of these should be mentioned, namely, those at the Euston Cinema and the Empress Cinema, Hackney, where the Neon display blends with the general design of the building, thus emphasising its architectural features. The largest Neon display in the United Kingdom—and one of the largest in the world—is on the point of completion in London on the New Victoria Cinema, a display which will produce a most attractive effect.

There has of late been a tendency to break away from the lettered sign and to introduce the pictorial element to a greater extent ; such change is to be welcomed, for the pictorial development of Neon lighting will be conducive to a less uniform and a more attractive appearance of streets. Amongst "pictorial" signs which add point to these considerations are the house and trees that dominate the Hampstead Road (London) premises of Oetzmann & Co., Ltd., and the unusual tramp steamer, with wave movement given by the use of a flasher, on the Kingston premises of G. Palmer & Sons. Somewhat different in technique is the "John Ginger" display at Huntley & Palmer's Reading Works, where Neon and floodlighting are combined to produce a most pleasing effect.

One of the most spectacular uses to which Neon has ever been put was for the illumination of the gigantic 90 foot Rainbow that dominated this year's Ideal Home Exhibition. The scheme was carried out in seven different colours, which covered the complete spectrum.

Smaller signs for window displays continue to be popular, and the Cleon and Ripple units already described in the *G.E.C. Journal* (Vol. IV, No. 1), have found wide acceptance. Various standard sizes and types of box sign have been made to suit individual requirements. Over 130 signs of a standard type have been supplied

Fig. 56.—Quebec Cafe, Lyons' Corner House, Marble Arch, illustrating the effect of luminous cornice treatment.

to Morris Motors, Ltd., for distribution to their agents all over the country, and a large quantity of Dunlop "Rainwear" signs are in course of manufacture. The neonised Osram Bulletin board on the Great West Road has introduced a type of advertising new to this country.

Fig. 57.—The dome of Derry & Toms' Restaurant, London, is illuminated by over 4,700 ft. of Neon tubing in three colours, in addition to 2,000 Osram architectural Striplite and other lamps.

No record of the year's developments in Neon illumination would be complete without reference to the magnificent interior lighting of the restaurant of Derry & Toms' new premises (fig. 57). A considerable number of possible changes of colour are provided, while the huge false ceiling is flooded with pastel shades unobtainable by any other means.

OIL-FILLED CABLES.

During the twelve months under review, 50 miles of oil-filled cable for working pressures from 33,000 to 132,000 volts have been manufactured at Pirelli-General Cable Works, bringing to a total length of 180 miles the oil-filled cable manufactured at this works, and installed in Great Britain.

These installations have largely been supplied to the Central Electricity Board and a description of them is given on page 68 of this issue.

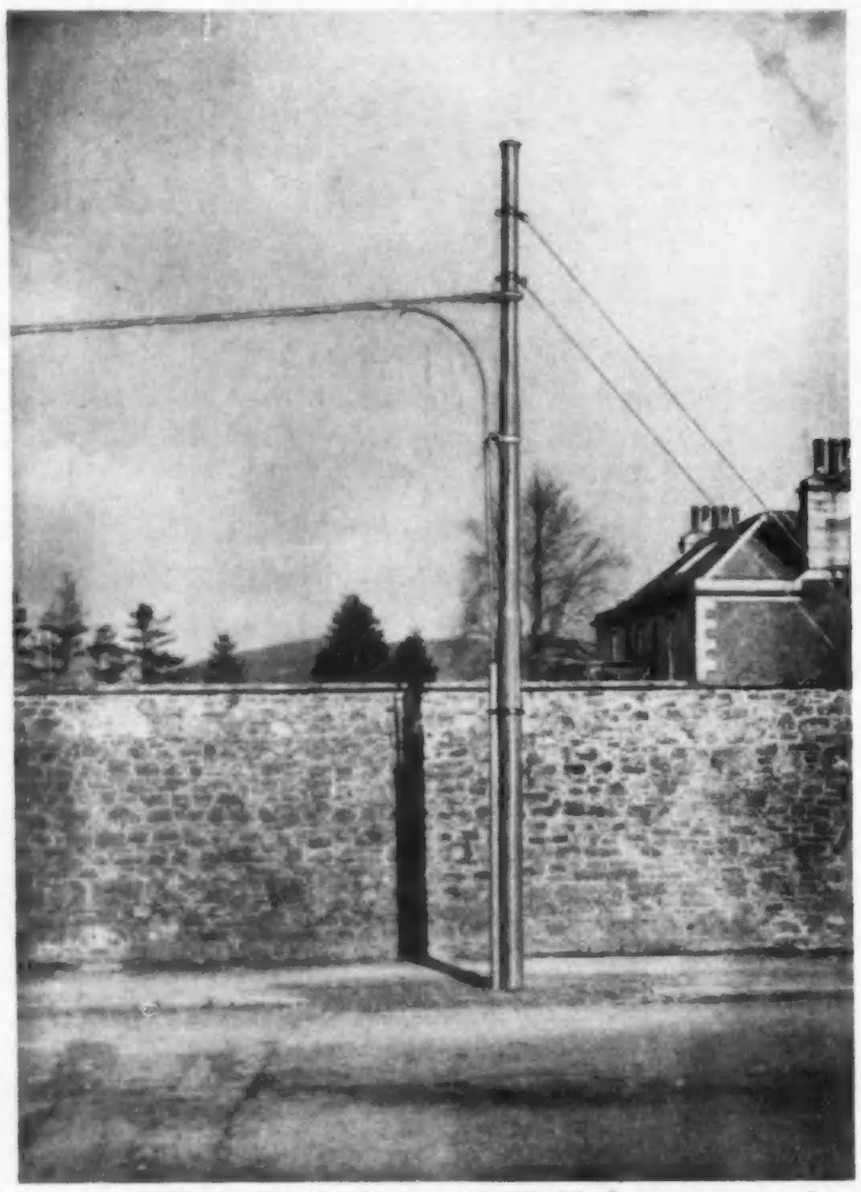


Fig. 58.—Terminal pole with H.T. catenary cable.

CABLE ACCESSORIES.

A new type of pole-mounting end-dividing box of the tier type has been introduced which is simple and effective, while a new range of disconnecting boxes meets the demand for a box in which installation costs are reduced to a minimum. This has been achieved without any increase in the initial cost to the purchaser and the boxes embody all the features of modern design in this type of main accessory. On test they have proved extremely efficient, both mechanically and electrically and are the subject of a new patent application.

TELEPHONE CABLES.

This year the Post Office revised their specification for trunk cables during 1933, and requested that these cables should be manufactured without the use of cellulose string on the conductors, as this material can only be purchased abroad. It was not possible previously to meet the Post Office specification without the use of cellulose yarn, but improvements in manufacturing methods and the types of machinery employed have now made this possible, and the cable supplied to the Post Office for the last three trunk contracts has been manufactured without cellulose yarn.

The factory equipment for the manufacture of the new type star-quad subscriber's cable was completed early in the year and has been working satisfactorily.

Cables of the ordinary trunk telephone type, but designed to withstand 2,000 volts to sheath, have been supplied and erected on aerial power lines to provide circuits both for power line protection and telephony.

A new type of pilot cable, called the earth conductor type, has been developed. This cable is a single-quad, solid paper, oil impregnated, lead sheathed and wire armoured cable. It is designed to be erected in the earth wire position on an aerial power line. The lead sheath and armouring provide the earth conductor for the power system, and by using the two pairs and the phantom circuit on these pairs, one telephone circuit and two circuits for power line protection can be provided.

The first cable of this type has been supplied and erected on a power line approximately 7 miles long.

OVERHEAD LINES.

In the early part of the year the first Pirelli-General patent catenary cable was erected and there has since been a steady demand for this type of overhead transmission line. In most cases the cables have been employed to meet the need for providing an E.H.T. supply along a route where overhead L.T. distribution is also required. The cable is normally of the paper insulated and alloy lead sheathed type and is bound to the supporting galvanised steel strand by means of suitable binding tapes or wires, the strand being supported on the poles by means of special suspension clamps which provide a flexible means of support. The whole installation is therefore suitable for use in roadside positions as large clearances from trees or buildings are unnecessary.

The insulator changing device which was first produced two years ago has been improved and is now available to suit both suspension and tension insulator strings. The device for use with suspension strings consists of a short beam designed for mounting on the crossarm end above the insulator string. Miniature winches at each end of the beam take the weight of the conductor, and a second pair of winches is provided which lift a light clamp secured to the insulator immediately below the unit to be replaced. When the weight has been

taken in this manner, the unit can be removed and replaced without difficulty.

In the case of the tension insulator changing device the construction is patented and has the valuable feature of being completely independent of the tower crossarm. Fittings are secured to both ends of the insulator string and are connected by two long-pitch roller chains, one on either side of the insulator string. The chains are permanently secured to the fitting at one end and can be attached at any point to the fitting at the other end, thus enabling strings of any length to be accommodated. Special tightening screws are provided to enable the conductor tension to be transferred to the device, which then becomes rigid and facilitates removal of the complete string or of a single unit.

TELEPHONY.

The world-wide adoption of automatic telephone systems has contributed in no small measure to the continual extensions necessary to the Telephone and Radio Works at Coventry. Though economic conditions in 1933 led to a decreased demand for new equipment, technical progress has been no less marked than in previous years. One example of progress is afforded by the still wider range of rural automatic exchanges now available, which has been responsible for the great improvement in telephone service in thinly populated areas. The latest addition to this range is a series of standard switching units from which can be built an exchange of any capacity up to 800 lines. The popularity of this type of equipment is also evidenced by a growing demand from overseas, particularly from those countries in which the problems of giving a first class service which approximates to those encountered when considering rural districts at home. This again has led to the development of further models designed for service under the climatic conditions obtaining in the Dominions and Colonies.

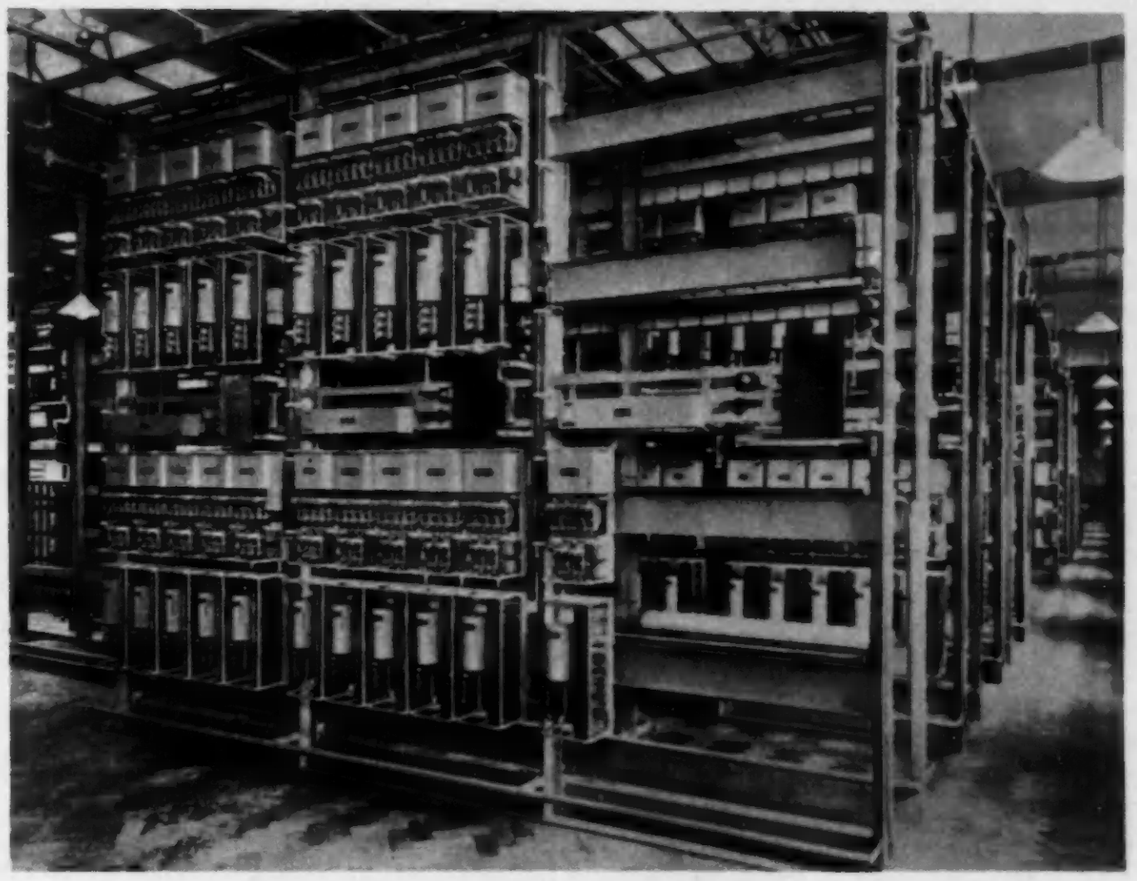


Fig. 60.—Director equipment, Kensington Telephone Exchange.

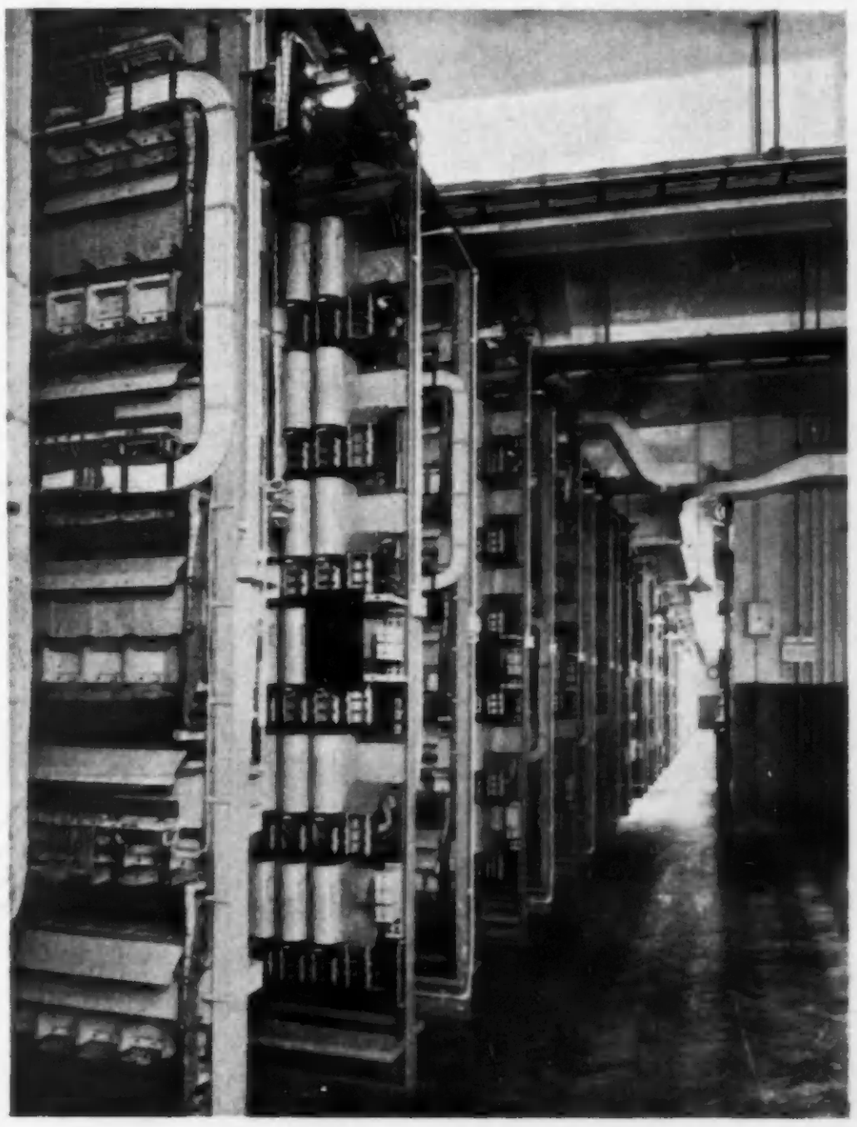


Fig. 59.—Selector racks, Kensington Telephone Exchange.

Of the large city exchanges completed for the British Post Office, perhaps the most notable is the Kensington equipment (fig. 60), which is one of the largest in Great Britain, providing capacity for 10,000 local subscribers' lines. It is designed to serve as a tandem switching centre for the whole of the west side of London.

The gradual conversion of the telephone system from manual to automatic working has been followed by further developments in the design of private automatic branch exchanges, in which various improved features have been incorporated with the object of simplifying and speeding up connections between P.A.B.X. exchanges and the public system.

Important research work has continued with the object of increasing the efficiency of the subscriber's telephone. Since the introduction of the modern bakelite instrument employing a transmitter vastly superior to earlier types, the question of overall performances has been the subject of closer investigation, the result of which is seen in the latest telephone giving maximum side tone suppression. The new Gecophone instrument (fig. 61) sets an improved standard

of articulation and successfully meets the conditions of both short and long lines. After comparative tests it has already been adopted for public service by various overseas Administrations.

REPEATER EQUIPMENT.

Advances have also been made in the field of

Fig. 61.—The new Gecophone Subscriber's Set.

long distance communication, particularly in the design of voice frequency equipment and carrier telephone systems. During the autumn of 1933

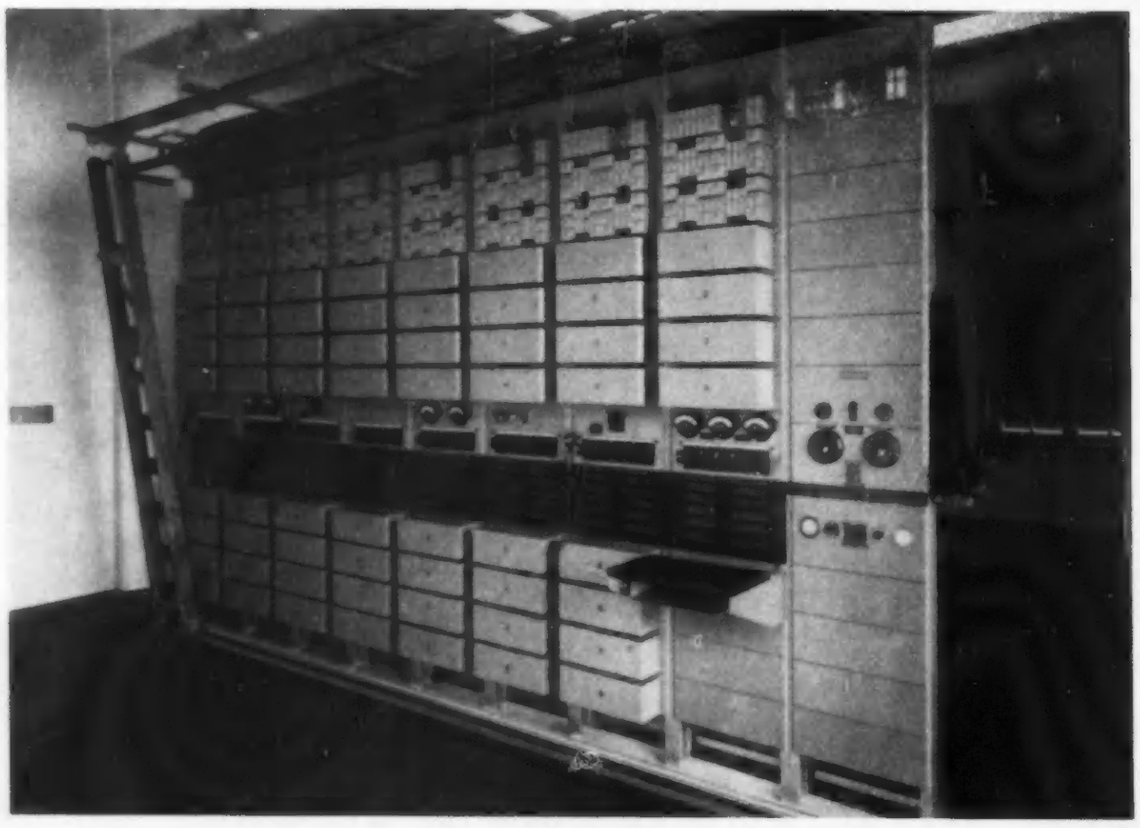


Fig. 62.—Repeater equipment at Tanta, serving Cairo-Alexandria trunk telephone circuits.

the first large telephone repeater station in Egypt was installed and commissioned. The station is located at Tanta, about midway between Cairo and Alexandria and works in conjunction with the Cairo-Alexandria loaded cable laid by Pirelli-General Cable Works in 1930. Capacity is provided for 200 repeaters, the initial equipment comprising 60 2-wire repeaters of a type specially designed for this installation. The work presented some interesting problems in frequency equalisation and the station is notable in that it is the first complete installation to employ the new 0.15 amp. filament valve developed at the Research Laboratories. As a result of this introduction of telephone repeaters, the trunk service throughout the Nile Delta has been improved considerably.

CARRIER CURRENTS AND SUPERVISORY CONTROL.

The subject of electrical communication to-day covers so wide a field that it is difficult to bring under one heading all activities in this direction. But it is convenient here to illustrate the close association now necessary between sections of the industry which, till quite recently, were rarely brought into intimate contact.

Two years ago the first installation in Great Britain of carrier current telephony superimposed on the conductors of a 132 kV power line was completed. This telephone circuit was operated by the Grampian Electricity Supply Co., Ltd., between the hydro-electric station at Rannoch and sub-station at Abernethy. In 1933, as a result of the proved reliability of the service, compared with that given by Post Office lines in the neighbourhood, which suffered severely during winter weather, the Post Office approved connection of the circuit to the C.E.B. control line from Abernethy to the Glasgow Control room of the Central Scotland Grid.

With the opening of the Grampian Company's hydro-electric station at Tummel at the end of 1933 this system was greatly extended and, for the first time in Great Britain carrier circuits over the power transmission lines were employed also for supervisory control purposes. Two distinct carrier circuits were formed (fig. 63); one from the new Tummel Station to Rannoch and one from Tummel to Abernethy. In addition to the speech facilities provided over each of these circuits, that from Tummel to Abernethy also provides a channel for the supervisory control from Tummel of the whole of the 132 kV and 33 kV switching plant at Abernethy. The supervisory control of the Rannoch hydro-electric station over its carrier circuit is also projected and provision for this extension has been made in the existing equipment.

The supervisory control equipment allows some 50 operations to be carried out at the remote point and gives continuous indication of the condition of all switchgear. In addition a number of remote meter readings are given.

Telephonic communication between Rannoch, Tummel, Abernethy and Glasgow is also extended by means of an earth-wire pilot cable on the Perth-Abernethy 33 kV line to Perth generating station, with provision for extension later to the administrative offices of the Grampian Company at Perth. A small automatic exchange at Abernethy provides

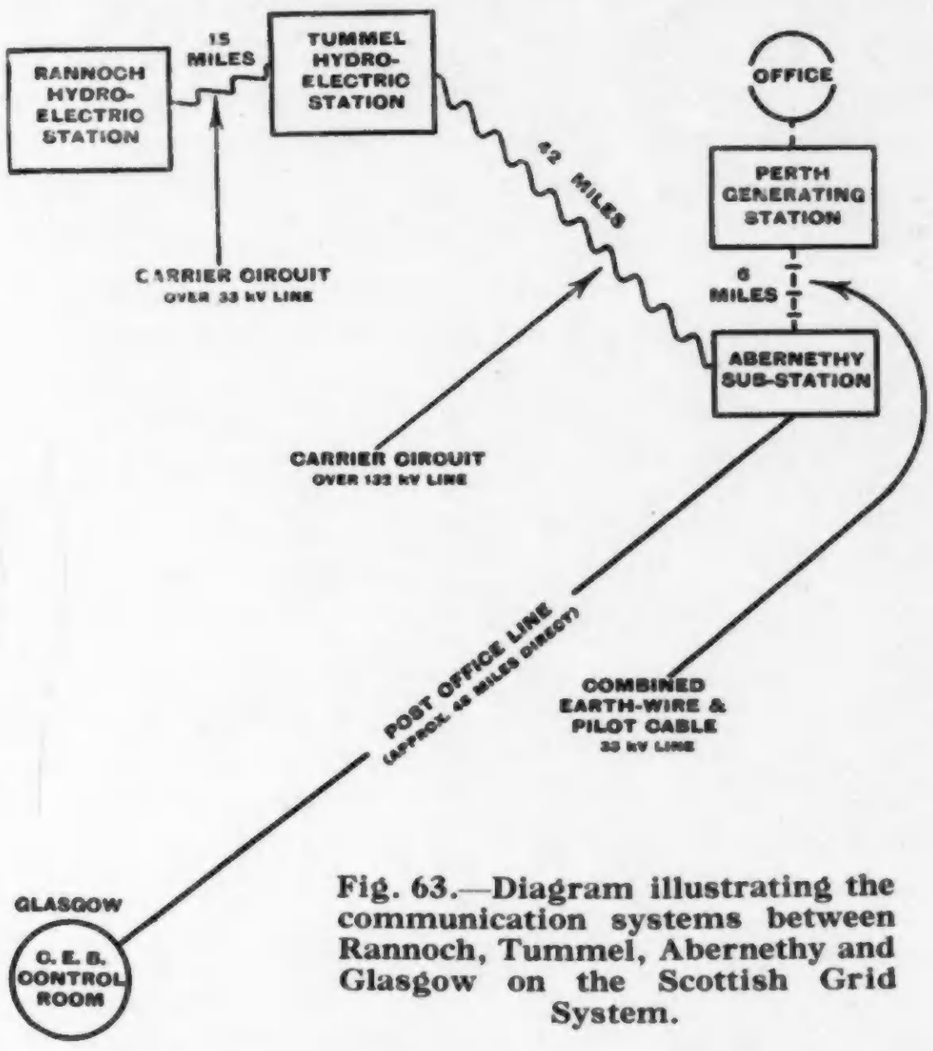


Fig. 63.—Diagram illustrating the communication systems between Rannoch, Tummel, Abernethy and Glasgow on the Scottish Grid System.

a complete system of calling by dialling over the various channels—carrier, earth-wire pilot, or Post Office line—between the points mentioned, facilities being given whereby certain important stations may break in on an engaged circuit if the exigencies of the service so demand.

The earth-wire pilot cable between Perth and Abernethy is of the type recently introduced by Pirelli-General Cable Works and consists of a two pair lead covered paper cable having a galvanised steel wire sheath which serves not only as support and protection for the pilot cable but also as the earth wire for the transmission line. In this case the two pairs of the cable provide one telephone circuit and two feeder protection circuits.

The scheme as a whole is an interesting example of the diversity of facilities which can be given over communication channels wholly controlled by the power undertaking. Moreover, these facilities have been provided, so far as the sections Rannoch-Tummel and Tummel-Abernethy are concerned, merely by the addition of terminal equipment and without in any way interfering with the overhead lines, while between Perth and Abernethy the slightly heavier earth-wire pilot cable has been erected in place of the two earth wires for which the line was originally designed, without involving additional clearances or strengthening.

SOUND AMPLIFYING EQUIPMENT.

A wider appreciation of the variety of purposes which may be served by sound reproducing systems has been followed by an increased demand for amplifying equipment of all types. The range of standard amplifier units has been extended and certain series have formed the basis of systems designed to meet specific requirements. An example is to be found in the Broadcast Call System introduced for service in hotels, factories, hospitals, stores and similar organisations in which the need often arises for the transmission of urgent instructions either to a number of persons or to one individual whose whereabouts may not be known. The use of a network of loudspeakers controlled from a central microphone has proved to be infinitely more flexible and effective than lamp signalling or bell systems and there is now available a standard range of apparatus from which can be built up a "broadcast" system of any size.

A typical mains driven equipment as employed for "paging" systems in hotels is shown in fig. 64, this cabinet incorporating a standard 12-watt amplifier capable of serving over 100 loudspeakers.

Further progress has been seen in the development of radio relay systems in this country, a notable

Fig. 64.—Mains-driven broadcast call equipment for hotels, factories, hospitals, stores, etc.

feature being the general adoption of standard panel type rack-mounted units. To the existing range has been added a new large power output panel employing the Osram DA. 100 valve and giving an A.C. output of 60 watts.

GECALLOY CORES.

The developments in the production of new small high permeability Gecalloy cores for special loading purposes was described in *G.E.C. Journal* (Vol. IV., No. 1), and during the past year large numbers of these cores have been utilised for the loading of junction cables, especially in and around London. Several pots containing as many as 300 coils of this type have been manufactured, and the small size of the container (11″ × 11″ × 26″ high), indicates the advantages in the loading of junction cables in conjested town manholes where space is the vital factor.

Until the beginning of last year, loading coils of the dust core type had only been used for a frequency range up to about 20 kilo-cycles. But continual progress has been made in the production of dust core material for radio frequencies, and a range of Gecalloy radio cores has been made available for the manufacture of turning inductances for wireless sets. These cores are manufactured in the form of straight rods or in toroidal form similar to the cores used for lower frequencies. The Gecalloy radio cores give a very large reduction in size compared with the usual type of air-core coil, but at the same time there is a considerable improvement in performance due to the reduction of losses; the actual resistance figures are about one third those of a typical commercial air-core coil. The manufacture of these cores from raw materials is now being carried out at Salford Works.

Besides the cores for low and high frequencies, another set of cores for use for frequency ranges between audio and radio frequencies has been developed, so that a highly efficient screened inductance can now be made to operate at any desired frequency. This is of considerable importance in view of recent advances in various types of communication circuits at intermediate frequencies.

RAILWAY SIGNALLING.

The railway signalman operates the points and signals under his control by a form of lever, whether the operation is entirely manual or effected by the medium of power.

The lever form of control has been retained in power operation because it has proved convenient for associating with mechanical interlocking—the only trusted means for many years of securing proper sequences of movement and preventing irregular and accidental movement.

It was only recently that the attitude of mind which accepted the efficiency of electrical controls for outdoor work, but did not trust them for internal interlocking, was demonstrated to be illogical; in consequence, a rational development made the electrically interlocked lever frame an established fact. An opportunity for breaking away from the "lever" precedent in this country came with the re-signalling in conjunction with the York to Northallerton main line widening. The modern version of a signalman's operating panel is shown in fig. 65. It was designed by the Siemens and General Electric Railway Signal Company and manufactured in the G.E.C. Wembley Works.

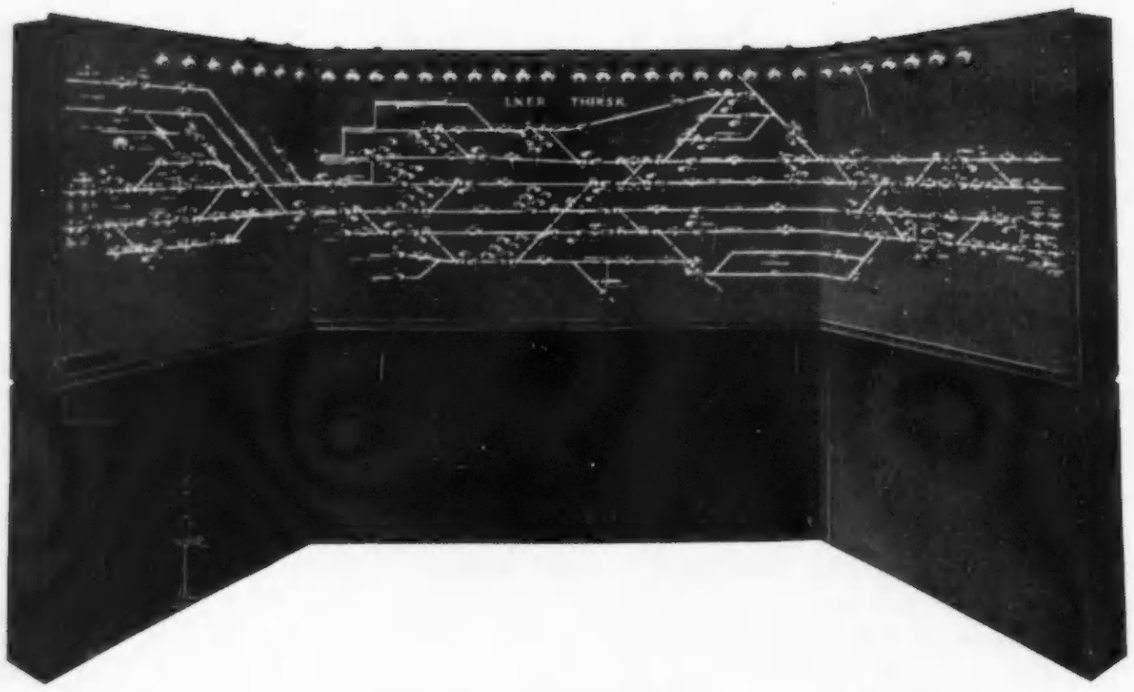


Fig. 65.—Signalman's operating panel supplied to the L.N.E.R. in connection with the York to Northallerton main line widening.

The scheme is extremely simple. At Thirsk the signalman sits before a panel only 12 feet in length upon which is a diagrammatic representation of the 4½ miles stretch of permanent way which his signal system covers. On the diagram he can see the "lie" of every pair of points which he operates, by means of small indication lamps situated at the point location. A black band, either horizontal for the through lines or oblique for the turn-out, is exhibited across the middle of the lamp cover glass. The position and movement of all engines and trains within the control area are indicated by red lamps set in pairs astride the tracks. These red lamps are illuminated by the presence of trains

on the relative sections of track outside and are extinguished when the tracks are clear.

The control switches for the signals are manipulated by turning a small knurled knob through 90°. In the knob itself is an indication lamp which is lighted when the signal is giving the danger aspect, and another lamp alongside the knob is lighted when the signal is showing a clear aspect, that is, either yellow or green.

The turning of a signal switch is the only movement necessary in order to set correctly all the points on the route to be taken by the train and to clear the signal itself after an indication is received that the route is properly set up.

Along the upper part of the panel is a row of switches for operating the various points individually. These, however, are not normally used because routing is effected by the signal switch and they are left in a neutral or central position. The various signal switches are not directly interlocked, the interlocked controls being transferred to multi-contact relays located in a separate room.

A power interlocking frame would have occupied three times the length of the Thirsk panel and would have necessitated the employment of two signalmen.

MEASURING INSTRUMENTS AND APPARATUS.

The more accurate measurement and detection of small alternating voltages and currents has been the subject of much investigation at Salford Works, and greater accuracy over a wide range of frequency has been obtained.

Methods for the application of thermionic valve circuit technique to apparatus for measurement and detection have formed one of the chief lines of development, and for apparatus constructed on these principles the actual indicating instruments are of great importance especially the more sensitive types of moving coil instrument. The $2\frac{1}{2}$" type, which can be made up to first grade accuracy in most instances, is now used for currents when the full-scale deflection is less than one milliampere, without undue sacrifice of robustness and damping. For cases where a larger scale is required the $3\frac{1}{4}$" round or square types have many applications and a series of these instruments has been developed.

Types of instruments which embody these small meters in conjunction with valve circuits include valve voltmeters and ohmmeters, A.C. bridge apparatus for various purposes and A.C. potentiometers, detector units for bridges and potentiometers with indicating instruments, valve oscillators for test and measurement purposes, cathode ray oscillograph units and telephone attenuation measuring apparatus.

The construction which is being applied to this range of apparatus is illustrated by the power unit for a cathode ray oscillograph (fig. 66). The container is made of sheet metal (generally sheet iron) which combines lightness with great strength; sharp edges are entirely avoided. Unless appreciable heat is likely to be generated, the components can be totally enclosed as the container can be made dust-proof and moisture-proof. The metal construction ensures good electrostatic and electromagnetic screening which is very important. The indicating instruments are also usually in metal containers. All the valve circuits are arranged for operation from either A.C. or D.C. mains.

Some of the instruments mentioned above merit further description.

A multi-range mains operated voltmeter developed at the G.E.C. Research Laboratories is particularly suited for laboratory and test purposes. Five ranges enable accurate voltage readings to be

Fig. 66.—Power unit for a cathode ray oscillograph.

taken from 0.5 to 150 volts with frequencies between 1000 and 2000 kilocycles. The reading is only slightly affected by variations in the mains voltage, and compensation is provided for voltage variations up to 20 per cent. The Osram ML4 valve which is used is decapped to give low capacity and low losses at high frequency, and for these reasons also, the input switch is made with high insulation value and fitted with special earthing arrangements. This voltmeter was designed originally for separate mains and instrument units, but is now developed as a single instrument with the all-metal construction described.

Up to the present time the usual detectors for use on alternating current circuits such as bridges and potentiometers have been—

(*a*) the vibration galvanometer for low frequencies.
(*b*) the telephone for audio-frequencies.
(*c*) the telephone in conjunction with a heterodyne detector for higher frequencies.

There are various difficulties encountered with the use of each of these methods. The vibration galvanometer needs constant adjustment, is not portable and is normally costly if great sensitivity is required. A quiet room is needed for the use of

the telephone as a detector and this is often difficult to arrange, especially where a bridge requires to be portable.

The new detector unit of the range under consideration, consists of a valve amplifier connected to a metal rectifier unit through a step-down transformer which indicates on a $2\frac{1}{2}''$ two pivot instrument of conventional type. The instrument is arranged to give deflections which vary logarithmically in order that the greatest sensitivity shall be at the zero end of the scale. This is obtained by using a rectifier element as a shunt across the instrument; a more detailed description will be found later in this article. A three-position sensitivity switch is also added which enables good control to be obtained over the very wide range of input voltage which occurs in the balancing of a bridge.

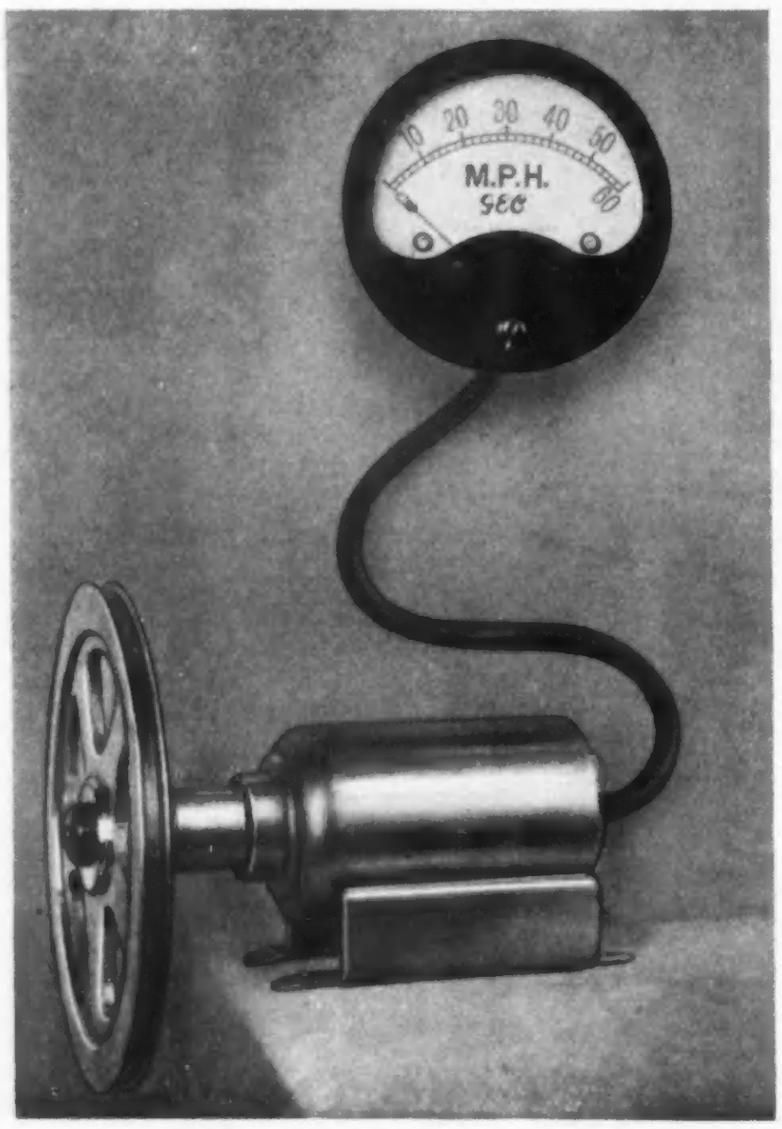


Fig. 67.—Remote indicating electrical tachometer.

For impure wave forms filters are added in order that the balance point shall be indicated at approximately zero deflection on the instrument. The apparatus is also arranged for the use of telephones so that the unit is then acting solely as an amplifier. The usual range can readily be increased or altered by a redesign of the transformers and a modification of the rectifier arrangement.

The use of valve oscillators for testing purposes has been of great importance for some time for measuring apparatus working at all frequency ranges. Compact mains operated oscillators have been developed along similar lines and with similar construction to the other apparatus described here, and are now suitable for laboratory and general testing purposes. Small heterodyne oscillators made on these lines are applied to various production tests and are now developed for the testing of uniformity of metal wires, bars, strips, etc., by running the samples through a coil connected to the oscillator. A similar application can be made to thickness testing by use of a condenser arrangement instead of the coil.

The metal construction is also being applied successfully to compact portable A.C. bridges and A.C. potentiometers operated from the mains. The use of detector-amplifier units and compact oscillators described above is of value because the apparatus can be built up on the unit principle and various components can be interchanged.

Cathode ray equipment is being increasingly adopted in connection with all electrical measurements to-day, and a set has been developed at Salford consisting of three components, the mains power unit (fig. 66), the "sweep circuit" unit, and the tube holder. These units are all constructed in all-metal containers giving compactness and good screening, together with the great advantages of portability.

For testing materials at voltage above that of the standard insulation tester with hand-operated generator, the valve rectifier has large possibilities and a set has been introduced which gives pressures up to 1000 volts and is operated from the A.C. mains. The instrument reads directly on an ohmmeter scale. The apparatus consists of the indicating instrument, a transformer for stepping up the voltage, and the rectifier valve and a larger series resistance to protect the moving coil of the instrument, and also the operator. In practice the mains can be left switched on and a continuous direct current high voltage supply is available for testing without the need for any attention from the operator.

Extended use is being made of metal rectifiers for measurements over the complete audio-frequency range with a view to utilising the principle of rectification for a number of uses in telephony and audio-frequency apparatus where a high degree of reliability and accuracy are required. For this purpose, investigation has been made in order to detect small frequency errors and those due to temperature variation. The thermocouple instruments hitherto used for this purpose have the disadvantage of mechanical weakness and slowness of indication, and the development of metal rectifier instruments indicates that there is a considerable field for their use for frequencies above the power supply range. The temperature errors are compensated and the instruments can either be calibrated at any particular frequency or can be

adjusted to 1 per cent accuracy up to 5,000 cycles per second, or even higher. Voltmeters of this type are made with a minimum full scale deflection of 1.0 volt and standard ammeters have a minimum full scale reading of 1.0 milliampere. Multi-range instruments of these types have been developed and many of the disadvantages in this respect due to the inherent properties of the rectifiers not having a linear resistance characteristic have been overcome.

The property of the non-linearity of metal rectifiers has been utilised to produce instruments with logarithmic scales which have long been advocated as the ideal type of instrument.

The method of obtaining a logarithmic scale is that developed by Dr. L. E. Ryall. It consists of shunting the instrument movement with a metal rectifier disc. At low deflections the impedance of the disc is high compared with that of the instrument and the shunting effect is almost negligible. As the current increases, however, so the impedance of the disc is reduced, and the shunting effect becomes more pronounced. The rectifier shunt principle can be applied either for direct or alternating current and tests have shown it to be of considerable value in a variety of apparatus where the logarithmic scale is of special advantage.

A remote indicating electrical tachometer (fig. 67) has been designed to form a serviceable and accurate electrical speed indicator applicable to engines, presses, winders, automobiles, pumps and for many

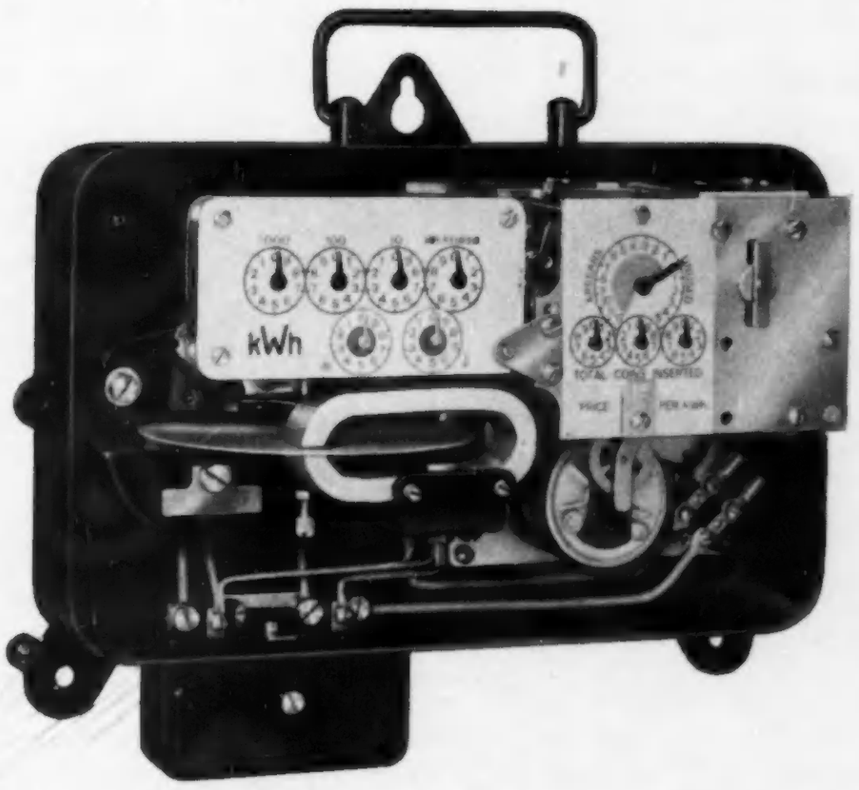


Fig. 68.—Chamberlain & Hookham two-part prepayment meter with cover removed to show mechanism.

other purposes. A rotating permanent magnet is driven from the machine whose speed is to be measured and a stationary armature is mounted on a screw adjustment adjacent to the pole faces. The armature winding is connected to a dry plate rectifier (using the centre tap circuit), which is contained in the generator body.

The D.C. output may be connected by means of a compensating distribution box to any number of standard moving coil instruments which may be situated at any distance from the generator. Alternatively, one instrument may be used with any number of generators which have been adjusted

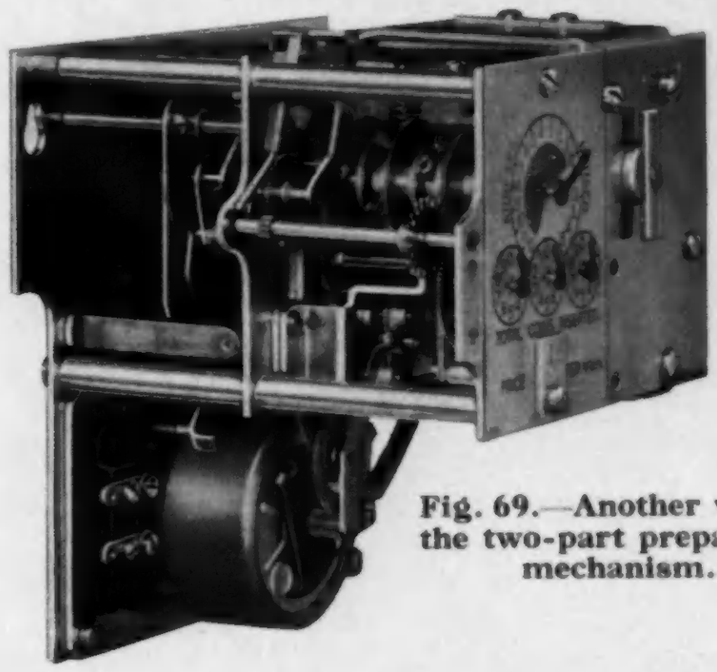


Fig. 69.—Another view of the two-part prepayment mechanism.

to give the same voltage, by means of a suitable switching system. The generators are wound for a normal maximum speed of 2,000 r.p.m., but they may be run up to 3,500 r.p.m. for short periods.

ELECTRICITY METERS.

Many improvements have been made in connection with prepayment meters. Hitherto they have been supplied in cast iron cases due to the preference expressed by purchasers. There is, however, an increasing demand for a lighter meter and to meet this a single phase prepayment meter is now manufactured in a pressed steel case. The weight of this instrument is 9½ lbs. as compared with 19½ lbs. for a similar meter in a cast iron case. A steel case prepayment meter is similar in appearance to the two-part prepayment meter shown in fig. 68, differing only in the "coins unused" dial.

The present-day tendency is for the price of current to be reduced for domestic purposes, and where prepayment meters are installed this necessitates an alteration in the gearing controlling the price per kWh. An improved price change mechanism has been introduced which reduces this to a very simple operation. The price change mechanism consists of two wheels and pinions held in a small bracket. This bracket is held in position by a shouldered peg and a screw. To change the price per kWh the screw is slackened a few turns and the bracket is removed. A similar bracket with the appropriate gear ratio is substituted in its place and the screw is tightened up. The operation can be accomplished in a few seconds by an unskilled person and correct meshing of the gears is determined by the shouldered peg and the screw, which latter has a conical head fitting into a countersunk recess in the bracket.

Prepayment meters used in connection with fires in hotel bedrooms are provided with a resetting device which enables the mechanism to be set to zero and the switch to be opened by depressing a key. When a guest vacates his room it frequently happens that a portion of the electrical energy for which he has paid remains unconsumed. By setting the mechanism to zero the hotel proprietor obtains the benefit of this unconsumed energy instead of the incoming guest. In the new steel case meter, the resetting device has been simplified and improved. It now consists of a flat spring having a conical projection on one end. This spring can be depressed by the insertion of a key through the cover of the meter. When this operation is performed the bracket which carries the price change gear is moved slightly into a position where it allows the gear train to disengage at one point. A spring then causes the mechanism to run to zero

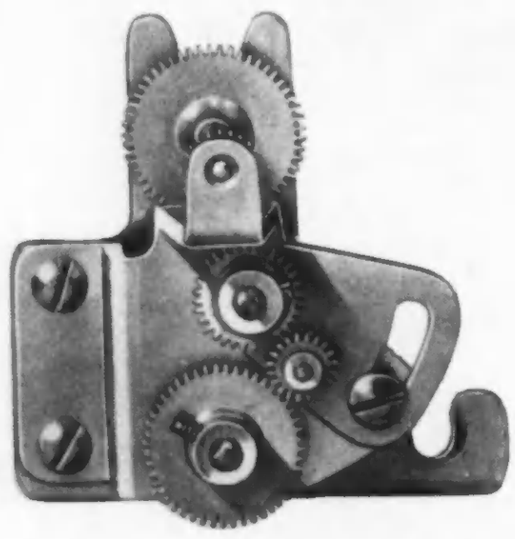


Fig. 70.—Rental price-change mechanism for two-part prepayment meter.

and open the switch, which cannot again close until a coin is inserted.

A two-part tariff for the supply of electricity to domestic consumers is being adopted extensively. This tariff takes the form of a fixed annual charge plus a small running charge. For a small consumer having an electric cooker, an annual charge of say four pounds, or about 1/6 per week would be usual, plus a running charge of, say, ¾d. per kWh for all current used, whether for lighting, heating or cooking.

For a consumer having a quarterly account, this tariff presents no difficulty from the metering point of view. The prepayment consumer, however, cannot so easily be dealt with, since the standing charge must be collected independently of the amount of current consumed. To meet this difficulty a two-part prepayment meter has recently been introduced in which provision is made for registering the standing charge on a time basis concurrently with the registration of consumption. A two-part prepayment meter with the cover removed is seen in fig. 68.

The meter embodies a modification of the well-known Chamberlain & Hookham prepayment mechanism in which the insertion of a coin closes a switch enabling the consumer to obtain a definite quantity of electricity. The switch opens after this amount has been consumed, unless meanwhile a further coin has been inserted. The opening of the switch is controlled by a meter element which allows the prepayment mechanism to run in the opposite direction to that in which it is moved by the inserted coin.

The modification consists of the addition of a small synchronous motor which runs continuously and drives the prepayment mechanism in the same direction as the meter. The rate at which the motor drives the mechanism is determined by the standing charge to be collected, suitable gearing being interposed for the purpose. Assuming that the standing charge is one shilling per week and that one shilling has just been inserted in the meter, the switch will be closed and the consumer may take a supply of current if desired. Should current not be used, the synchronous motor will drive the mechanism for one week at the end of which time the switch will open the circuit. On the other hand if a supply of current is taken, the rate at which the mechanism is run down will be accelerated by the meter in proportion to the consumption and the switch will open correspondingly earlier. The complete prepayment mechanism in the form of a removable unit is seen in fig. 69; the small synchronous motor will be observed at the lower half of the illustration.

If, after the opening of the switch, another coin is not immediately inserted in the meter, the motor will continue to run and register arrears against the consumer. Still bearing in mind the previous example, if no coin is inserted in the meter, the arrears will accumulate at the rate of one shilling per week. In meters of this type, hitherto available, no further supply of current could be obtained until the whole of the arrears had been paid off. Strictly speaking this may be regarded as legitimate, but it is at times very inconvenient. A consumer having accumulated arrears to the extent of say, three shillings, wishes to obtain a supply of current. Before this can be done he must find three shillings to pay off the arrears and one additional shilling to prepay for current. Unless he has at least four coins of the right denomination, no current can be obtained. To overcome this objection, provision is made whereby, no matter how much the consumer is in arrears, the insertion of one coin only will provide a limited supply of current, sufficient for an emergency. Thus, the insertion of one shilling when the consumer is in arrears with his payments will provide him with about three pennyworth of current and cancel ninepence of the debt.

This is a convenience which will be greatly appreciated by consumers who may have difficulty in finding a sufficient number of coins to cancel all

the arrears. If the small amount of current made available is not immediately made use of, the value is automatically transferred to the cancellation of arrears, and if, twenty-four hours later, current is again required, a further shilling will have to be inserted. Also a succession of coins inserted will advance credit on the first coin only. Thus, a consumer who is five shillings in arrears can obtain credit to the value of about threepence on the first coin he inserts. If five coins are inserted in succession he will obtain credit to the value of threepence and the balance of four shillings and ninepence will go to pay off arrears. But if the five coins are inserted at intervals, allowing the switch to trip before another coin is put in the meter the consumer will obtain credit each time. The effect of this improved device is that the consumer is enabled to pay off his arrears by instalments instead of being compelled to pay them in a lump sum. In many cases this results in increased revenue since the consumer is always assured of a limited supply of current for each coin inserted notwithstanding the fact that he may be in arrears.

Apart from the use of this type of meter for the collection of a standing charge, it can also be used for the collection of hire charges on apparatus, rental on wiring, the purchase of electric irons, kettles, heaters, and the like. The gear train between the synchronous motor and the prepayment mechanism is provided with a removable element which may readily be altered by changing a wheel, to accommodate a wide variation in the weekly fixed, payment. The price per kWh is also adjustable in this meter in the same simple manner as obtains in the ordinary prepayment meter. The small removable gear train for varying the standard charge or rental may be seen in fig. 70. The charge is altered by changing the bottom wheel which is secured to its arber by means of a grub screw.

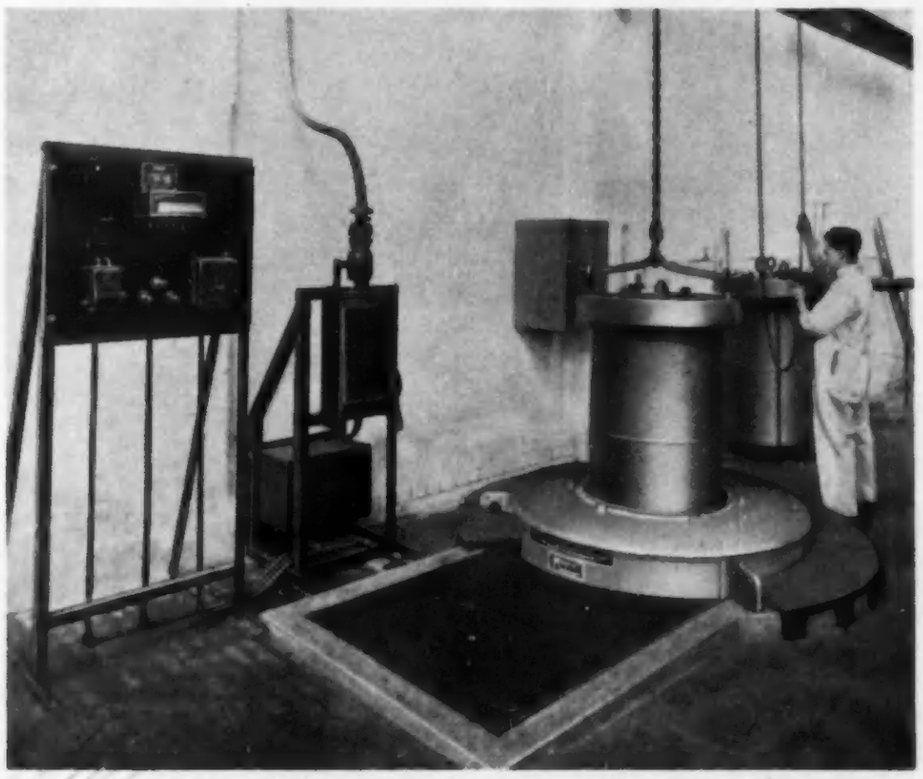


Fig. 71.—Lowering a charge into a G.E.C. (Grunewald) bright annealing furnace.

ELECTRIC FURNACES.

The past year has been notable for the further development of the Grunewald bright annealing process, three installations having been put into successful operation in this country. The process is making considerable headway, particularly for the bright annealing of iron, steel, nickel and copper strip and wire in coils. It is also used for bright annealing nickel alloy coinage blanks, fine copper wire on spools, etc. Copper strip and wire are being annealed with an energy consumption ranging from 90 to 120 kWH per ton, and steel strip is being annealed at 720—730 deg. with an energy consumption of 170—180 kWH per ton, where recuperation is obtained by placing ingoing cold pots and outgoing hot pots in a thermally insulated trench for recuperative purposes, and 200—220 kWH per ton without recuperation. As a commentary on the quality of the anneal, it is interesting to note that the Grunewald process although essentially a bright annealing process, is being adopted in some cases where a bright finish either is not required or is of secondary importance. This is due to the very high degree of uniformity of the heat-treatment; chains and Diesel engine pistons may be cited as examples. Screws and other small pieces which can be contained in a basket or pot which is annular in plan are also being annealed by this process.

Fig. 72.—Another view of the furnace illustrated in fig. 71; installed in the works of The Hall Street Metal Rolling Co., Ltd., Birmingham.

One of the installations referred to is adapted so as to use the G.E.C. (patent) controlled atmosphere process of bright annealing for certain non-ferrous metals to be used in addition to the Grunewald process.

The application of the nitriding process for the surface hardening of special steels and irons has been extended to the hardening of brake drum liners and nitri-cast-iron cylinder liners. Several electric furnaces have been built during the year for use with this process and are now operating both at home and overseas.

A considerable amount of investigation has taken place in connection with the Witton high frequency induction type electric melting furnace (Stobie Patents). A complete installation is now in course of manufacture for a well-known Sheffield firm of steel manufacturers.

One important installation of resistance furnaces carried out during the year is a complete furnace equipment for a mill to produce aluminium strip for the manufacture of foil. This plant comprises an electric melting furnace having a hearth capacity of 1 ton and arranged for lip axis pouring; a small melting and holding furnace to be used for topping up ingots; a re-heating furnace for heating ingots for hot rolling, and an annealing furnace for annealing strip in coils. All these furnaces are subject to automatic temperature control, and interesting mechanical and automatic features have been introduced in the case of the re-heating furnace.

ELECTRODE CIRCULATORS AND STEAM GENERATORS.

Several electrode steam generators and hot water circulators have been put into service.

Of these, a 500 kW 400 volt circulator is used in conjunction with storage tanks to heat a cinema. The equipment is fully automatic in operation. Power is switched on by the operation of a thermostat in the main storage tank, provided the time switch is making contact to indicate an "off peak" period. The main contactor then closes switching on the circulator at minimum load. The load control relay now takes charge and raises the loading to full load by modifying the relative position of the electrodes.

A circulating pump also starts and continually circulates water from the storage tank through the electrode circulator and back to the storage tank. As the water heats up its resistance falls and the load regulating relay suitably adjusts the position of the electrodes to maintain a constant electrical load.

When the water in the storage tank reaches its maximum temperature the thermostat operates to reduce the load to a minimum, the main circuit is then opened. The operation of the time switch during a period of "peak load" causes a similar operation.

A 100 kW steam generator for a laundry operates at 60 lbs. sq. in. gauge pressure. The plant is designed to operate automatically, the average height of water in the generator being regulated to suit the demand.

WATER HEATING.

A capsule thermostat has been developed for controlling the heat of water in domestic hot water storage tanks. It is particularly suitable for use with immersion heater sets designed for attachment to existing coal heated storage cylinders which require to be either electrically heated or electrically boosted. The thermostat is secured to the tank side by one bolt only through which the heat from the water is conducted to the active element of the thermostat.

When water reaches the operating temperature of 170°F. a capsule filled with a special volatile liquid distends, causing a rapid break between a pair of silver contacts. The contacts have been specially designed to break up to 15 amperes on alternating current circuits only. The capsule is mounted on the metal base of the thermostat.

The mechanism is totally enclosed by a moulded bakelite cover which is sealed down at the works.

ELECTRIC COOKERS.

Domestic electric cookers are being standardised wherever possible in order to effect a reduction in the number of types previously considered necessary.

Fig. 73.—Typical "Magnet" electric cooker.

It is gratifying to record the headway which electric cookers are making in the homes of wage earners. Schemes inaugurated by supply undertakings involving free installation and slot-meter collection have proved a valuable aid to this class of business. The increased use of "Magnet" cookers overseas has to be reported; various prominent municipalities in the Dominions now instal large numbers of these cookers on hire purchase terms.

The heat storage cooker is being more widely used, and there seems little doubt that with the further development of the heat storage principle the demand for this type of cooker will increase still further.

The subject of electric hotplates was very fully dealt with in a recent article in this Journal (*G.E.C. Journal*, Vol. IV, No. 3, p. 139). It remains only to state that the output of these appliances has doubled during the past year, and that they are being supplied to all leading British cooker manufacturers.

ELECTRIC CLEANERS.

A new de luxe model of the "Magnet" electric cleaner has been introduced during the year. It embodies many excellent features tending to increase the ease with which it may be used and the efficiency of its operation; in addition, the design has been very carefully reviewed, particularly in respect to those points which in the past have not received sufficient attention. Thus the new cleaner is provided with a nozzle adjustment lever for different thicknesses of floor covering, the opening of the

Fig. 74.—One of the range of G.E.C. radio receivers; the 8 valve "superhet."

bag is very large so that the dust may be easily withdrawn, the dust sleeve inside the bag coupling prevents dust falling out of the bag when in use, also the automatic switch is very conveniently arranged.

RADIO RECEIVERS.

Considering the range of radio receivers as a whole, a great change was made during 1933, all except the very cheapest sets being designed to embody super-heterodyne principles. Circuits generally have tended to become more complicated, necessitating new methods for testing the sets in the factory.

From the point of view of the user, however, the sets have been much simplified, distinct advances having been made in tuning arrangements.

A point of great importance lies in the fact that all sets are despatched from the factory with the set of valves with which they have been tested and passed out by the final inspection department.

Progress has been made in power amplifier design, neater layouts having been introduced, and equipment for a Broadcast Call System, suitable for use in factories (see p. 39) is now being made, also a 60-watt amplifier panel for radio relay work.

In the short wave field a commercial radio receiver for the reception of Empire transmissions has been introduced; it is suitable for supplying these transmissions to radio relay services overseas.

RADIO VALVES.

The range of Osram valves is continually being extended in order to cater for the many and varied requirements of modern receivers. It would not be possible in a general article to describe all the characteristics of the new valves introduced during the year, but reference should be made to the more prominent types.

First in interest (apart from the new "Catkin" valves already mentioned), is a double diode triode for A.C. and D.C. mains (the Osram M.H.D.4 and D.H.D. respectively), designed in connection with automatic volume control.

The term double diode triode requires some explanation. It is a multiple valve consisting of three electrode systems on one cathode, the object of which is to provide (1) diode rectification (2) automatic volume control, and (3) triode amplification.

A particular feature of this type of valve is the provision of most effective shielding between the diodes and the triode element. This latter feature is of the utmost importance in a valve of this type. It has been shown that the double diode triode in amplified automatic volume control provides adequate control, and the choice of a triode amplifying element ensures the maximum consistency between valves which is another most important requirement of the method.

There are several other new valves for A.C. mains, two of which belong to the H.F. screen pentode class. One of these is a straight screen pentode (type M.S.P.4) and the other a variable mu adaption of it (type V.M.P.4), The particular feature of these valves is the provision of a 7-pin base. This allows the metal coating on the bulb to be brought to a separate pin and earthed. The H.F. pentode lends itself particularly for the design of new sets, and provides greater voltage amplification without distortion.

The straight type M.S.P.4 is also very useful as a combined detector oscillator in super heterodyne sets or as a sensitive detector in "straight" sets.

There are also included in the A.C. mains range two new indirectly heated rectifiers (types M.U.12 and M.U. 14), which show an advantage in slow heating and therefore avoidance of voltage surges.

They possess a lower impedance and therefore give a better voltage conversion ratio.

Another valve is the P.T.16 which is a directly heated large power output pentode particularly suitable for large amplifiers and de luxe radio gramophones. It is capable of an output of over 6 watts for a dissipation of 16 watts, obtaining its efficiency by virtue of the fact that the screen and anode voltages are rated to be similar, namely 300 volts each.

The new cathode developed at the Research Laboratories makes possible a valve of shorter length with much higher mutual conductance. In addition, these new valves and future A.C. valves will be fitted with a double helical spiral heater. The method of construction of this heater has the effect of neutralising the magnetic field set up by the A.C. current through it. This has led to the production of high slope valves (such as the M.H.41 type) which give very little hum in view of their high magnification. Such valves exhibit the standard filament rating of 4 volts 1.0 amp.

One more new type should be noted, namely, the D.A.100. This is a large power output triode with a high undistorted output designed specifically for broadcast relay systems and public address amplifiers.

The advance in valves for 2-volt circuits is also noteworthy. The most spectacular innovation is a valve of the double triode "class B" type "B.21." It should be mentioned that "class B" valves involve a method of operating an amplifying valve so that its standing anode current depends on the strength of signal, and for a very small standing current, the power output under working conditions may be very considerable. The B.21 differs from other valves of the same type in that it requires to be operated with a negative grid bias. This is an immense advantage in helping to provide better quality reproduction. Another feature of the B.21 is the duplicated grid construction which gives a better output-to-input ratio and thus higher efficiency.

Another new 2-volt valve of great interest is the V.P.21 variable mu H.F. pentode which is the first battery H.F. pentode to be placed on the market.

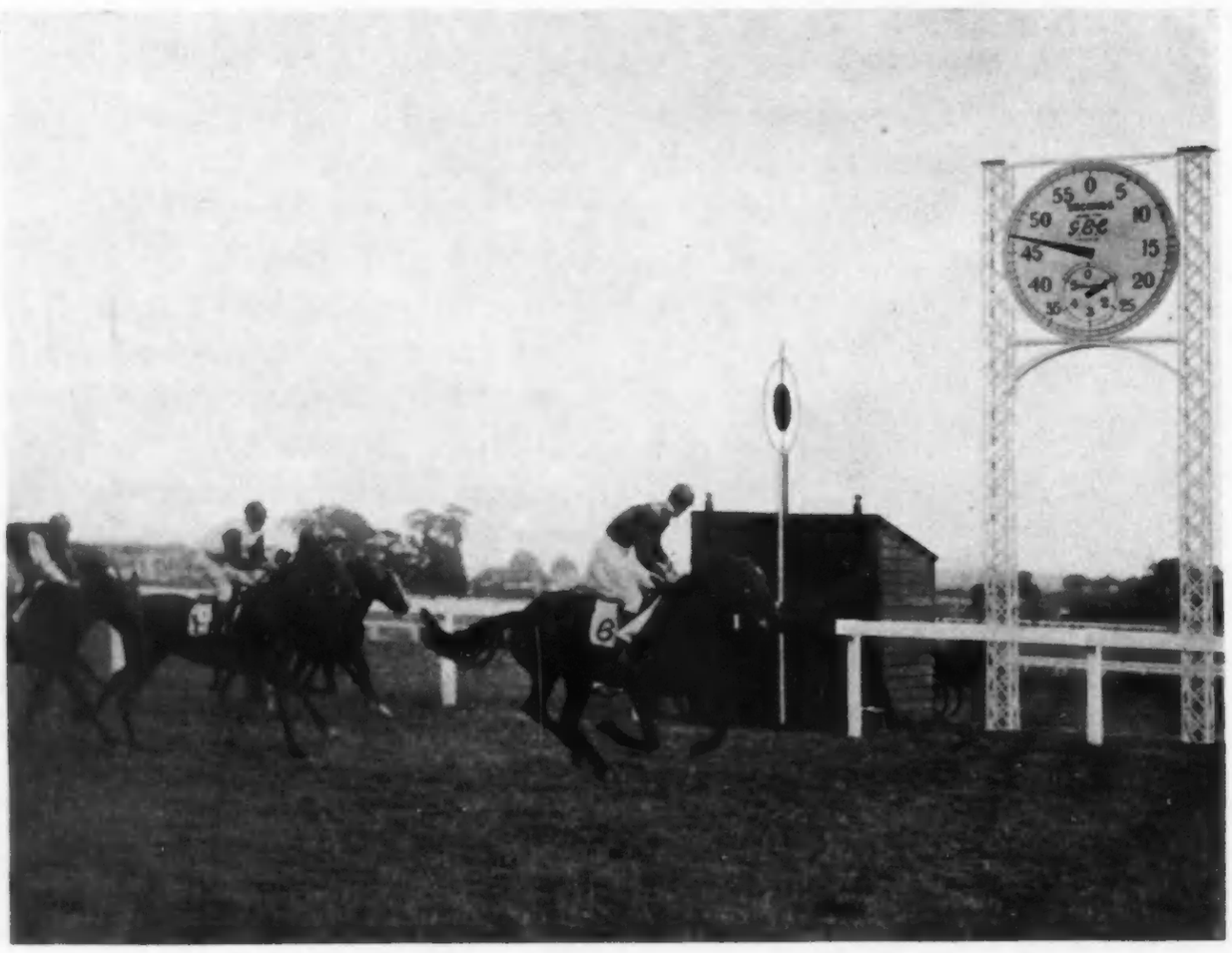


Fig. 75.—An application of the Osram photo-cell equipment is the timing of horse races.

The advantages of the H.F. screen pentode are particularly apparent in 2-volt valves, where a greater output can be obtained with the low H.T. voltages common in battery sets.

Other new 2-volt valves which are widely used are three screen grid valves, bearing type designations S23, S24 and V.S.24 respectively. They are designed specially for low H.T. current and absence of microphony.

APPLICATIONS OF PHOTOCELLS.

An installation, which is the first of its kind using a photo-cell, has recently been completed at Northolt Park for timing horse racing; it may well be the forerunner of a number of similar installations for recording flat racing. The recording is shown on a 7ft. diameter clock which is graduated in $\frac{1}{10}$th seconds to record up to a total time of 6 minutes (fig. 75).

The starting gates which are at various distances up to a maximum of two miles from the finishing point are each fitted with a push contact which

automatically closes the clock circuit when the gate goes up at the start of the race. At the finishing point a beam of light spans the course, the width of which is about 90ft. and the first interruption of this beam by the winning horse, stops the clock. A small switchboard is under the judge's control, which enables the recording to be stopped in the case of a false start or a disqualification.

Installations of smoke detecting gear have been put in at the chief offices of the Asiatic Petroleum Co. and the Cumberland Hotel, Marble Arch. The photoelectric gear is fitted to the uptake of the boiler flue and during periods when the smoke produced is negligible, a green lamp shows on the front of the boiler. When smoke is produced the ray is cut off and the relay switches the lamp from green to red to indicate to the stoker that the firing is bad.

An equipment is now working on the Waterloo (Bakerloo Line) station to give passengers warning when stepping on to the train. The station platform forms an arc of a circle and since the entrances to the train are in the middle of the coaches there is a gap between the station platform and the floor of the carriage, so that passengers are liable to miss their footing and go down the gap. The light beam and photocell amplifier span the track at the point where the driver's cab usually stops, so that when the train comes to rest the relay switches on all the lamps round the edges of the platform, the sudden illumination drawing attention to the gap and warning the passengers. This is a typical instance where any kind of mechanical contact closed by the train itself would be uncertain and might even be considered dangerous.

BATTERY MINE EXPLODERS.

A new patented design of exploder for firing shots in mines (fig. 76) has been approved by the Mines Department, as intrinsically safe for use in fiery mines. It is available in two models, for H.T. and L.T. voltages respectively.

The H.T. model is energised by a 3-volt dry battery and an impulse of about 40 volts is generated by charging up and de-energising a small kicking coil, wound on an iron core. A shot is fired by connecting the detonator up to the portable jack and inserting this in the exploder. The action of pushing the jack into the exploder operates a timed contact arrangement which gives only one impulse to the fuse head. The jack has to be completely withdrawn and re-inserted before another impulse can be produced.

The L.T. model is similar to the H.T. model in many respects, but operates directly from an 18 volt dry battery. There is no kicking coil in this model but the timed contact applies the 18 volts to the fuse head for a period of approximately .2 seconds for each operation by the jack.

In addition to the introduction of these new battery exploders, H.T. and L.T. magneto type exploders have been redesigned. They also comply with the requirements of the Mines Department.

MINE COMMUNICATION APPARATUS.

The increased stringency of the requirements of the Mines Department, which was referred to earlier in this article has led to modifications in the design of mining telephones, mining bells, mine pulls and rappers. All this apparatus is now certified either as flameproof or as intrinsically safe for use in any type of mine.

A new type of battery has been produced for mining purposes. Apart from the ordinary porous pot Leclanche battery it is the only battery which is certified for mining use.

ELECTRIC LIGHTING SWITCHGEAR AND ACCESSORIES.

Several new forms of small switches such as are required for lighting circuits and domestic appliances have been introduced, while many detail

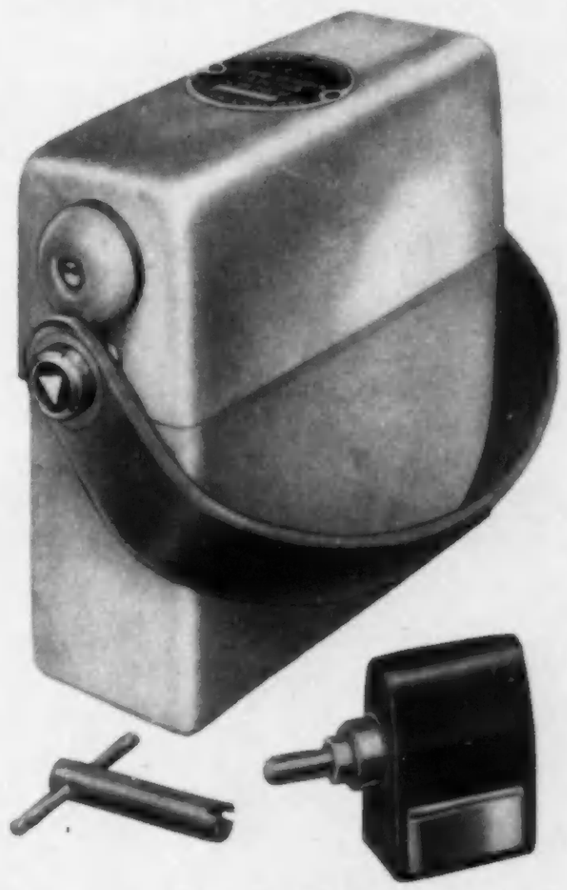


Fig. 76.—Battery mine exploder, as approved by H.M. Mines Dept.

improvements to existing designs have been effected. It is only possible to refer to the more important features of these new and re-designed ranges of apparatus.

Of prominent interest is a one ampere time lag switch, which is proving of service in halls, on landings and staircases, in stockrooms and many other situations where lighting is only required for a limited period. The switch consists of a plunger operating an air dash pot, and at the end of the plunger there is a milled head which can be removed. Immediately under the milled head is an adjusting

screw so that quite considerable differences of time can be obtained by adjustment on site.

A skeleton type of radiator switch has been produced, embodying the feature that the fixed contacts are mounted beneath the top plate. They are thus kept free from the dirt and dust which tend to accumulate inside radiators. It is noteworthy that this switch is being used by many leading electric fire manufacturers.

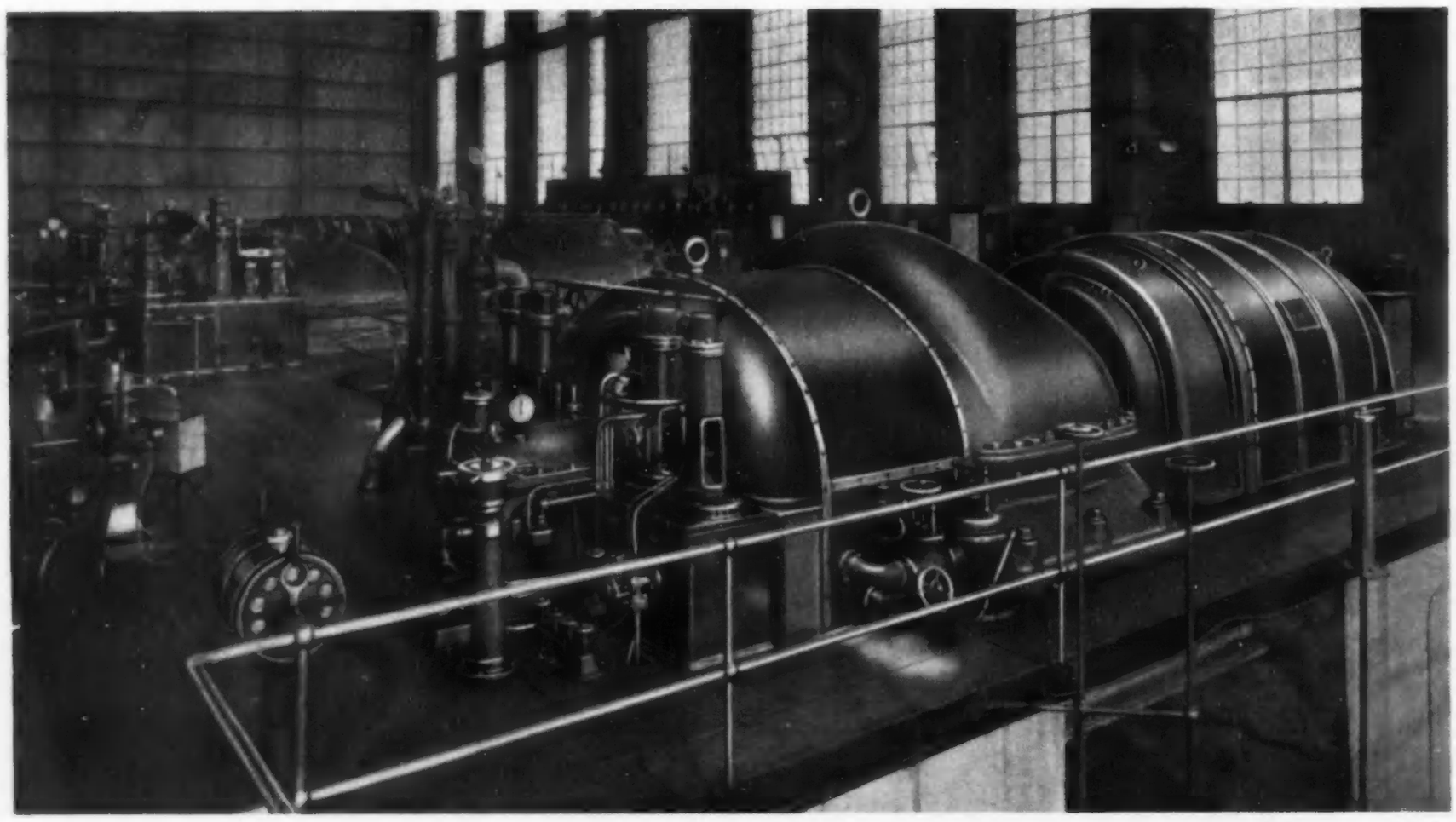
A range of 5 and 15 ampere 3 pin damper shutter type wall plugs and sockets has been designed. They are made strictly to British Standard gauge, but the shutters in the sockets are of the scissors type and neither of the line contact tubes is left exposed when the plug is withdrawn. The shutters are operated by the earth pin, the timing ensuring that they are moved from the entrance to the socket tubes just at the right moment so that the line pins on the plug do not foul the shutters. On the withdrawal of the plug, the shutters cover the socket tubes, and any arc which may be drawn when the plug is being removed with the current 'on' is immediately damped out.

A new lampholder, now available, can be attached to suitable twin cable at a moment's notice without any cutting or baring of conductors. The twin cable is laid in a groove in the holder and a wedge pushed home which causes pins to pierce the dielectric and make adequate contact. This ensures a watertight joint, and with the provision of a suitable india-rubber ring to fit over the B.C. lamp cap, the lamp also can be made watertight.

A patented twin ceiling rose is likely to be widely adopted. It has been designed to reduce the cost of wiring to the point over the bed to the minimum. The old method was to fix a ceiling rose at a point on the wall somewhere about the height of the picture rail, from which was suspended the pear switch, looping out from there to a position on the ceiling about 18 inches from the wall for the lampholder point. This made two wiring points, whereas by the adoption of the new design it is only necessary to wire for one point, and the flexible from the pear switch is taken along a channel in the moulding and looped at the ceiling rose from which the lamp pendant is suspended.

A lampholder designed expressly to accommodate the Osram architectural striplite lamp possesses an important feature which provides a greater measure of safely than has hitherto been attained. This added safety is afforded by a nickel plated phosphor bronze clip which encircles the lamp. The clip holds the lamp securely in position without risk of slipping.

G.E.C. Turbo Plant in South Africa.



Two 12,500 kVA, 3,000 r.p.m., G.E.C.-Fraser & Chalmers turbo-alternators in Johannesburg Municipal Power Station. An order for a third set of the same output has been received.

The Tracing of Ray Paths in Illuminating Glassware.

By J. M. WALDRAM, B.Sc., A.C.G.I., F.Inst.P.

Research Laboratories of The General Electric Co., Ltd., Wembley, England.

A LARGE amount of the equipment designed by illuminating engineers for the accurate control of light employs clear glassware, either silvered to produce a reflector, or moulded with a prismatic formation as a refractor. Whatever may be the particular manner of operation, every device of this kind intercepts a large amount of the

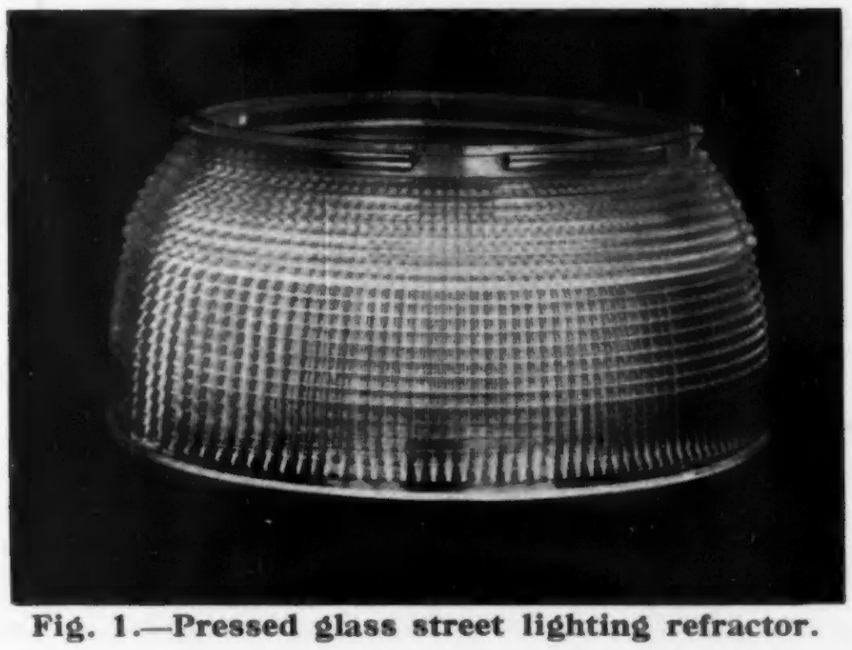


Fig. 1.—Pressed glass street lighting refractor.

light emitted by the lamp and redirects it to bring about some desired distribution of light; and all the light so redirected has of course to traverse the glass, either once or twice, before reaching the illuminated object. In the course of the development of glassware of this kind a need had often been felt for some means of investigating the passage of the light through the glass itself, for it was suspected that considerable losses might result, and the performance of the unit be marred, by small departures from the intended formation of the surfaces of the glass. That there is ample opportunity for such departures, can be seen from the photograph of a street lighting refractor in fig. 1, for it is moulded with 147 prisms, each of which has two or in some cases four surfaces, the angles of which should be accurate within 1°. Such a production is possible, and it is a tribute to the accuracy of pressed glass; but small errors in cutting of the mould which are almost impossible to detect by inspection may occur, and impair the efficiency of the device. The fluted glass reflector of fig. 2 appears a simpler problem, but the formation of the flutes involves even more difficulties in both design and production.

While the light distribution curve from the complete unit may give some indication of its overall efficiency, it will not be of much help in tracing the sources of inefficiency, or observing the detailed operation of the various parts of the reflecting or refracting surface. It was for this purpose, therefore, that the apparatus to be described was developed. The principle of operation is as follows.

The glassware under examination is cut at right angles to the length of the flutes or prisms to be considered, and the section ground flat but not polished. (The specimens can be cut in many cases with a heated wire, an initial scratch being made with a glass-knife). A piece of ground glass is held in contact with the cut section, the two ground surfaces being juxtaposed, but without cement between the surfaces. A spot of adhesive at either end of the specimen is sufficient.

If now a small projector is arranged to form an image of a slit parallel to the length of the prism or flute, and if the rays forming the image are arranged to fall on the flute adjacent to the section so as to graze the ground glass surface (the latter being inclined at a suitable slight angle to the axis of the projector) their path can be clearly seen not

Fig. 2.—Fluted glass reflector.

only before and after leaving the glassware, but also in the thickness of the glass itself, and any losses due to internal reflections, scattering or incorrect surface angles can be ascertained, together with their cause.

An apparatus has been designed with the object of making such examinations conveniently and rapidly, which has the additional advantage of

enabling measurements to be made. It is convenient to make the projector rotatable about an axis, so that the light apparently emanates from a point which can then be considered as a point

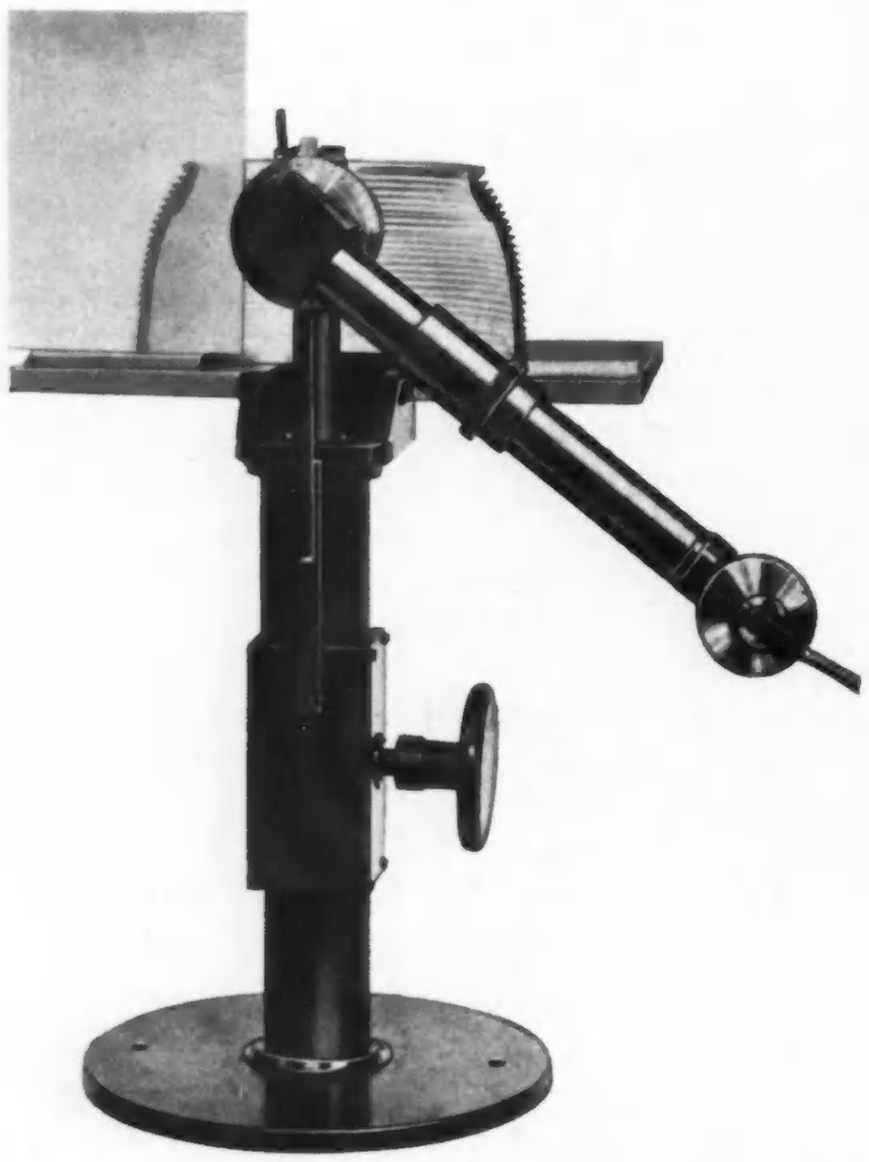


Fig. 3.—Apparatus for examining path of ray of light entering a reflector or refractor.

on the filament of the lamp used with the glassware.

The form of the apparatus is shown in the photograph, fig. 3, and the drawing, fig. 4. A central upright carries a horizontal table having a top which can slide horizontally over a limited range, upon which the specimen can be placed. The upright also carries a horizontal bearing at the top, in which the slit projector rotates, the projector being arranged in the form of a crank with right angle prisms at the corners. The projector itself consists of a lamp house at the end, with a 12v. 24w. headlight lamp with a straight filament, and a small double plano-convex condenser lens focussing an image of the filament on a slit. These components are fixed together as one unit and slide into the end of the body tube of the projector. An objective lens, adjustable in position by means of the loose ring on the outside of the tube, forms an image of the slit at a convenient distance from the last prism. The bearing of the projector is carried on a screw raising and lowering gear, whereby the height of the effective "source" may be adjusted relatively to the specimen.

In order to facilitate setting up, a scale of centimetres is provided on the table so that the specimen can be set centrally with respect to the axis of the projector; a scale of millimetres is provided on the vertical motion, and an angular scale divided to 5° is provided on the rotating part of the projector. Moreover, since the filament of a

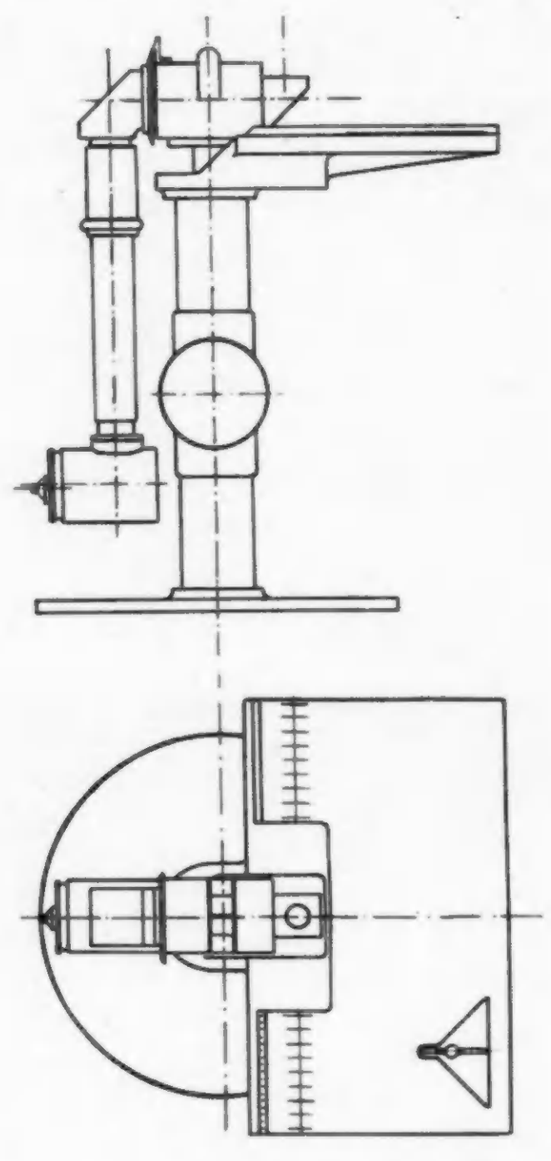


Fig. 4.—Arrangement drawing of the equipment shown in fig. 3.

lamp is a large source, it is often necessary to explore separately the light emanating from different parts

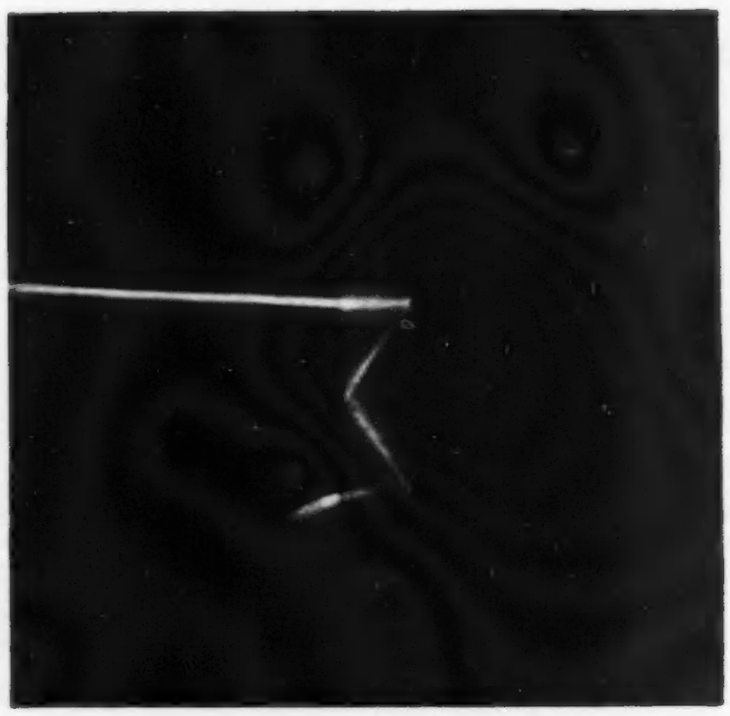


Fig. 5.—A ray of light traced through a fluted glass reflector.

of it, generally from one side or the other. Since in most cases the filament is in the form of a ring, this involves moving the specimen off centre by a distance equal to the radius of the ring to one side

or the other. For this purpose the table top is arranged to slide horizontally, and a scale of millimetres is provided in order to set the table at the required radius. In many cases it is desirable to shift from one side of the filament to the other and back

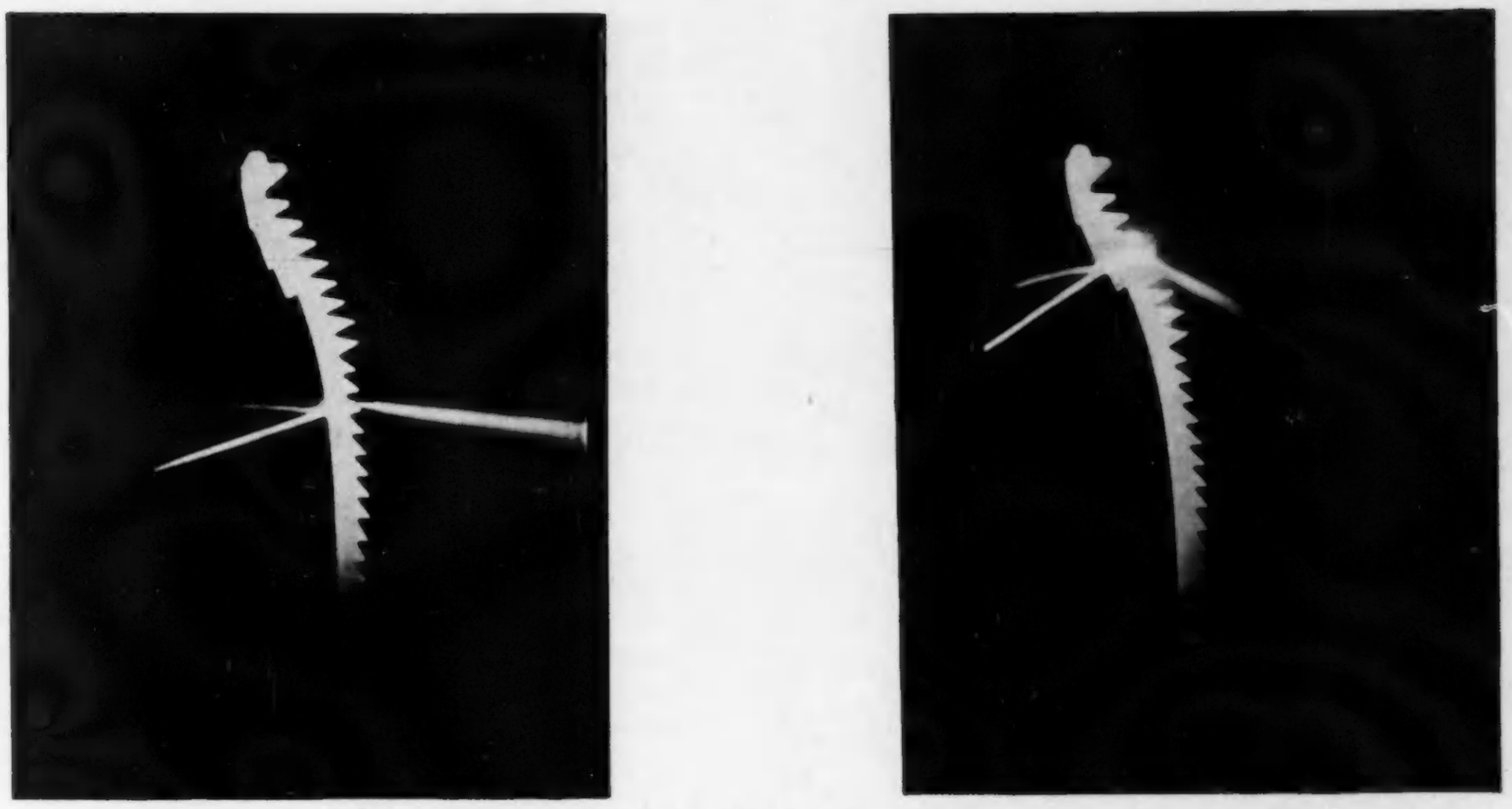


Fig. 6.—Sections of a street lighting refractor showing the paths of rays passing through a refracting prism (left) and reflecting prism (right).

again frequently, and an adjustable stop is therefore fitted to the table top, shown in fig. 4, consisting of a triangular hole in the table top and a sliding

Fig. 7.—Illustrating the loss of light in the last refracting prism.

pin in the fixed support, so that a restricted motion over the width of the filament to be used with the specimen can be given to the table. Once this stop is set, there is no need to read the offset scale when changing from one side of the filament to the other; the table is merely pushed from one side of the stop to the other.

Some of the effects obtained with fluted glass are shown in fig. 5. The specimen cut from the reflector is stuck on a vertical piece of ground glass fixed in a small stand. The specimen can either be arranged in proper relation with the filament, or if desired, the projector can be set horizontally, and traversed across the specimen using the vertical motion. In the photograph, the ray shown is that suffering the most spectacular departures from the desired path; it is not to be assumed that all the light falling on the surface is so treated. A reasonable deviation can be produced either by a small or by a large flute, provided that the angle of the flute is kept small. The losses in some very small flutes may be very large; and it has been noticed that similar losses also occur in certain types of figured glasses used for glazing windows. Some specimens, having deep facets, show an attractive and sparkling cut-glass appearance, which is regarded as an asset; and names are coined for the glasses which draw attention to this quality. But actually this appearance is brought about by total internal reflection, and is due to light which will, when the glass is installed, be prevented from entering the room.

The apparatus was, however, primarily intended for the exploration of refractors used in street lighting. The manner in which the prisms of a street lighting dome refractor operate can be seen in fig. 6. The lower prisms act by refraction, which in this case takes place mostly at the outer face of the prism, and bend light downwards. When the deviation required is too great for this

type of prism, the upper reflecting prisms are used in which the light is reflected from the upper surface.

Fig. 7 shows the loss in the last refracting prism, from the far side of the filament. Light from the near side can just be refracted as desired, but it will be seen that the light from the far side is

Fig. 8.—Loss of light occurring in a reflecting prism if the back face is not made at the most suitable angle.

entirely trapped; after reflection at the prism face it passes through the prism, is refracted further on passing the air gap between this prism and the next; is further deflected in passing through the next prism, and some passes nearly straight down through the body of the glass, some is reflected off the internal surface and emerges from one face or the other of the prisms much lower down the refractor.

Fig. 8 shows a type of loss which may occur in a reflecting prism, if the back face is not made at the most suitable angle. Light which reaches this face is reflected and passes out through the upper face well above the horizontal. This light would in practice fall on the reflector above the refractor in the lantern. In one case investigated, a refractor, designed to give the correct distribution without the lantern, was found to direct too much light downward when the over-reflector was added. This form of loss is known as "back-face" loss.

Another form of loss may occur in a reflecting prism due to light from the root of one prism being intercepted by the tip of the next prism. This is well shown in fig. 9, which illustrates one of the main uses of the apparatus in the checking of manufactured products. The prism shown was intended to have the upper face made with two slopes at a very slight angle to one another, but an error had been introduced in making the mould, resulting in the tip being cut too steeply. The result will be seen from the illustration. Light from the tip escapes in part by refraction instead of reflection, and goes above the horizontal; the remainder suffers complete tip loss, some of it being brought round in a complete circle and some escaping inside instead of outside the refractor.

Many other examples might be given of the exploration of prismatic lenses and other equipment, but the above will suffice to indicate the scope of the apparatus. It is not difficult to measure with fair accuracy the directions of rays after leaving the specimen, so that the exact effect of a flute or prism can be checked. A workshop protractor can be used, the straight edge being sighted against the ray on the glass and brought parallel with it.

Fig. 9.—Diagram showing the loss of light which will occur due to light from one prism being intercepted by the tip of the next prism.

In addition to the purpose for which the apparatus was originally designed, other very useful applications have been found. A projector which can produce a narrow pencil of light at given angles, or which can be conveniently moved parallel to itself, has many applications. It has, for instance, been used in the measurement of the angle and contour of flutes on glass.

Another use for the apparatus is in the exploring of the errors of a projection system used for giving beams of small angle. The apparatus may be used as above to project a series of rays parallel to the axis of the projector under test, which may be made to enter the projector and traced back to the source, so that the focal sphere of the apparatus may be found. In this way the errors in high-quality floodlight mirrors have been investigated successfully.

The Diesel Electric Tug "Acklam Cross."

By C. WALLACE SAUNDERS, A.M.I.Mar.E., A.M.I.C.E., A.M.I.E.E.
Marine Department of The General Electric Co., Ltd.

and H. J. COATES,
Switchgear Department, Witton Engineering Works.

The Diesel-electric tug "Acklam Cross" has many features of particular interest. Chief among these are, first, push-button control with battery operation of the generators to start the prime movers; secondly, the use of special high speed Diesel engines; and thirdly, the elimination of the usual engine hatch, affording a completely clear after-deck.

In the accompanying article the authors discuss these features in detail and give a full description of the electrical propulsion gear.

IT is particularly appropriate that the following description of the first British-built Diesel-electric tug should appear in this issue which contains a review of electrical progress and development during 1933, for the launching of this vessel on the 22nd June of that year marks a big advance in British shipbuilding.

The *Acklam Cross* was built by Hall, Russell & Co., Ltd., of Aberdeen, for the owners, Robinson & Crosthwaite, of Middlesbrough to the designs and specifications of R. Reid, Esq., M.Inst.N.A., Consulting Naval Architect of Hull, the electrical propulsion equipment being manufactured by The General Electric Co., Ltd., and the Diesel prime movers by Peter Brotherhood, Ltd. of Peterborough.

As a Diesel-electric vessel, the *Acklam Cross* is no novelty; as an electrically-propelled tug she is only one of many, some of which were built in America as far back as 1924. Her chief claims to the making of marine engineering history are that she is the first British vessel of her type, the first to have high speed Diesel prime movers, the first to have a clear after deck, and the first to have an electrical system of starting the prime movers.

Before describing the actual equipment of the *Acklam Cross* it may be of interest to outline the advantages of electrical propulsion, and more particularly Diesel-electric propulsion, for vessels of this class.

Fig. 1.—The Diesel-electric tug "Acklam Cross."

REQUIREMENTS OF A TUG.

The service which tug boats are called upon to perform demands certain conditions of operation which in other types of vessel are not perhaps so vital. The tug must be capable of being called upon for duty at a moments notice. Delay in setting out from the quayside may result in the loss of work. It must also be capable of rapid manœuvring when towing large vessels into and out of congested harbours, while of paramount importance is the ability to exert full power ahead or astern with the least possible delay in answering orders from the bridge.

Fuel consumption is another important factor. a considerable portion of the life of a tug is spent at the quayside waiting for work. In this respect, it may be mentioned that in order to be ready for service at a moments notice, a steam tug must keep steam up in the boilers, with the result that fuel is being consumed all the time.

ADVANTAGES OF DIESEL-ELECTRIC PROPULSION.

All the requirements mentioned are met by Diesel-electric propulsion to a greater extent than is possible with any other class of drive. The Diesel engine can be started up as quickly as a motor car engine, and during periods of inactivity no fuel whatsoever is consumed. The manœuvring capabilities of electric drive have been amply proved by existing ships in which this form of drive is employed. Reference to the trial results of the *Acklam Cross* given at the end of this article afford an indication of the remarkable degree of control obtained with electric drive.

Further, the use of electrical propulsion enables the ship-builder to select the smallest engine capable of dealing with the shaft horse-power required; and since the engine is run at a constant speed it is always ready to give its full output on demand. As both the generators and propulsion motors are inherently capable of dealing with momentary heavy overcurrents, they are able to exert considerably more torque at slow speeds for short periods than any other form of drive. Since all starting or reversing movements of the propellers necessitate movement from or through zero speed, it is evident that this ability to exert a heavy torque enables the operations of starting and reversing to be completed extremely rapidly.

A very important advantage of the electrical drive is the ability to split up the number of prime movers into two or more units per propeller. In this way considerable economy can be gained in fuel consumption during prolonged periods of running at reduced speeds, when one or more of the units

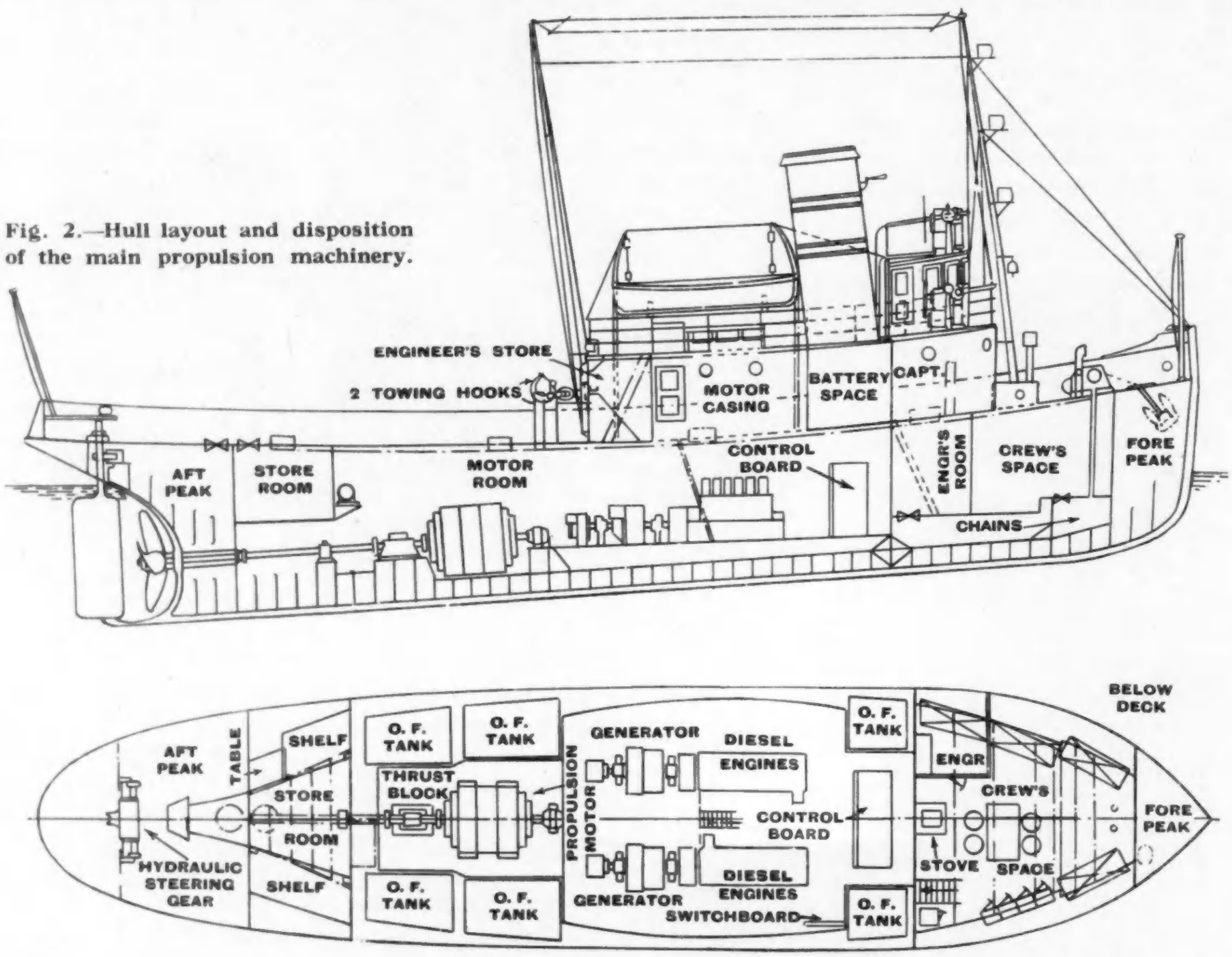


Fig. 2.—Hull layout and disposition of the main propulsion machinery.

(according to the number installed) may be shut down and the remaining units utilised to their full output (*i.e.*, at their highest efficiency). The splitting-up of the propeller units also affords stand-by plant in cases of emergency, such as breakdown of one of the prime movers.

One of the outstanding features of electrical propulsion is the simplicity with which the vessel can be controlled. It is practicable to place the control of speed and direction of propeller rotation directly in the hands of the navigating officer so that the movements of the bridge telegraph are immediately followed by the corresponding operation of the propeller motor, without involving the delay of even a few seconds which normally would be caused by the engineers in the engine room acknowledging the signals and performing the necessary operations.

All these features of the Diesel-electric drive are fairly well known and are to be found in most of the electrically propelled vessels afloat. The feature of the *Acklam Cross*, however, which is unique is the method of starting the Diesel engines. Usual practice is to start them by means of compressed air, necessitating the installation of compressors and storage bottles. In the case of the *Acklam Cross* a battery capable of giving a heavy discharge for short periods is used to "motor" the generators coupled to the Diesel engines and starting is consequently effected by the mere pressing of a button. Normally, the same battery is used for lighting and general distribution service.

PRINCIPAL DIMENSIONS AND GENERAL ARRANGEMENT.

The *Acklam Cross*, fig. 1, is a single screw vessel and her principal dimensions are as follows :—

Length overall	..	98ft.
Length B.P.	..	90ft.
Breadth moulded	..	22ft.
Depth moulded	..	11ft. 6ins.
Draught aft, normal		11ft. 10ins.

Not the least striking feature of the tug is her appearance. A good impression is obtained by the view at fig. 1, from which it will be seen that the masts and funnels are placed well forward, and that the after deck is completely clear. This arrangement has been made possible by the layout of the electric propulsion machinery and gives the *Acklam Cross* the distinction of being the first tug to have a clear after deck.

The hull layout and disposition of the main machinery are clearly shown in the accompanying general arrangement drawing, fig. 2. The hull construction is steel throughout and three watertight bulkheads divide it into four principal divisions,

Fig. 3.—One of the two G.E.C. 200 kW D.C. generators coupled in tandem to a 20 kW auxiliary generator, both being driven by a 300 h.p. Diesel engine.

Fig. 4.—View down centre of engine room looking aft. The propulsion motor can be seen in the background between the two Diesel engines.

comprising the fore peak, fore cabin, machinery space and aft peak.

The machinery compartment occupies the major portion of the ship's length and has an overall length between the bounding bulkheads of about 54 feet.

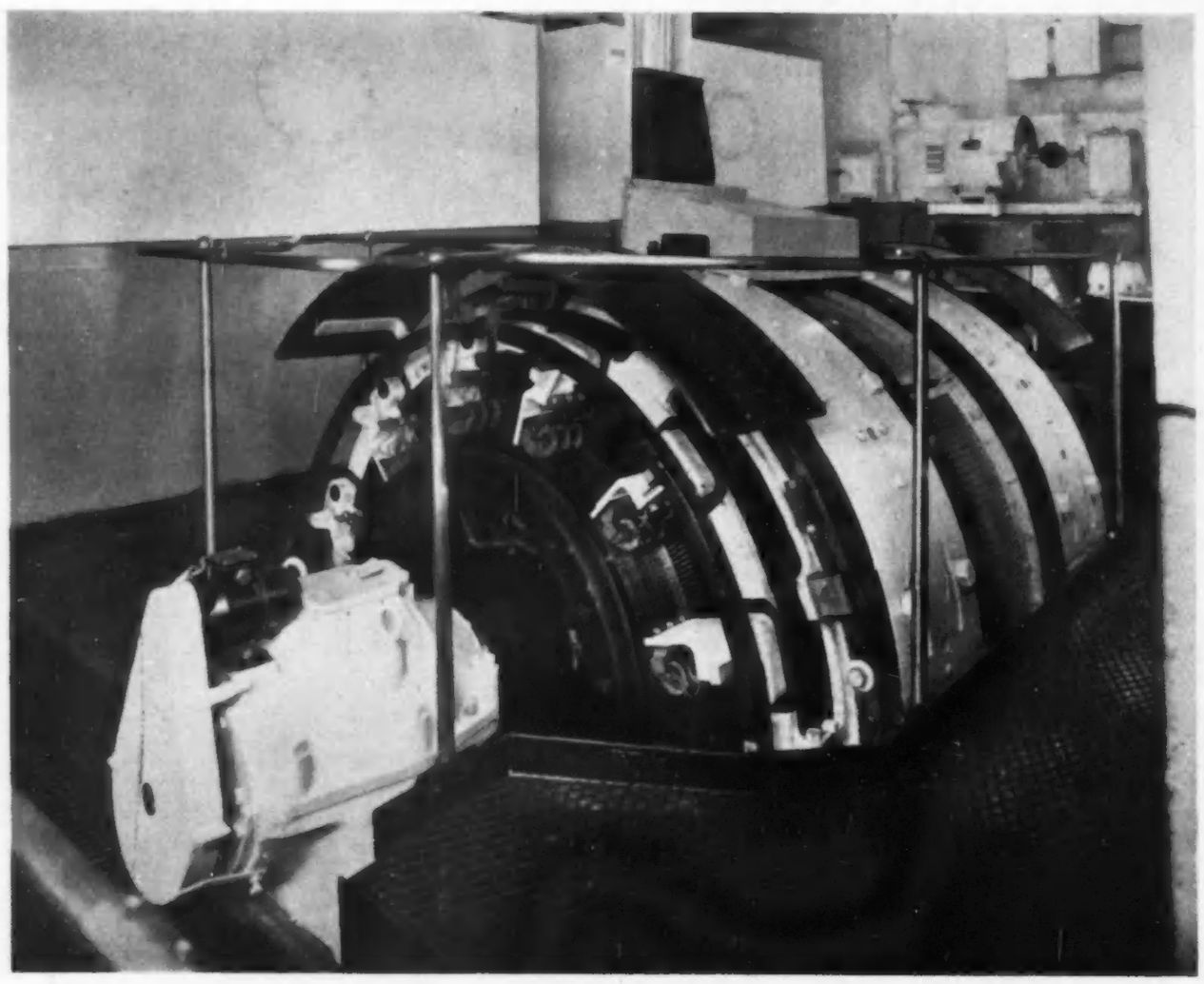


Fig. 5.—G.E.C. 500 h.p. 115 r.p.m. double armature propulsion motor direct coupled to the propeller shaft.

The Captain is provided with a well furnished cabin in polished oak, while there are also roomy quarters for the crew and a separate cabin for the engineer arranged forward. It is an interesting point that a crew of 4 or 5 is required for the *Acklam Cross*, whereas a compliment of 7 is usually necessary with the average steam tug of similar size.

PROPULSION MACHINERY.

The propulsion machinery of the *Acklam Cross* comprises two Diesel driven generator sets supplying current to one D.C. double armature propulsion motor which drives the screw. A view of one of the Diesel-generator sets is given in fig. 3.

Prime Movers. The two Diesel engines manufactured by Peter Brotherhood, Ltd. are of the four-stroke sleeve valve type, each having six cylinders, 7½in. bore by 12in. stroke and developing 300 b.h.p. continuously at 900 r.p.m. The engines run at constant speed in opposite directions and are placed abreast in the engine room as indicated in fig. 4.

The guaranteed fuel consumption, assuming a nett calorific value of 18,000 B.Th.U. for the fuel used, are as follows :—

Full load	..	0.38lb. per b.h.p. per hour.
¾ load ..	..	0.39lb. per b.h.p. per hour.
½ load ..	..	0.44lb. per b.h.p. per hour.

These figures were considerably improved upon during shop tests.

Electrical Equipment. Coupled to each engine in tandem are a 200 kW D.C. generator and a 20 kW auxiliary generator (fig. 3). Each main generator is direct coupled to the engine without any intermediate bearing, the two main generators being electrically connected in series each giving a voltage of 250. The windings are shunt wound with interpoles, and as each machine is separately excited the voltage may be varied from plus 250 to minus 250 volts. In this way it is possible to control the generator on the Ward Leonard system. The magnet frames of the main generators are of fabricated construction. On each frame, which consists of an all-steel fabrication split along the horizontal axis, are bolted the main laminated poles and solid interpoles. The field shunt coils are excited by a 110 volt supply taken from the auxiliary generators.

Each auxiliary generator is of sufficient capacity to supply all excitation and about 4 kW for other auxiliary drives. The generators are of the multi-polar type, compound wound, the magnet

Fig. 6.—Wheelhouse showing control pillars interconnected with those in the flying bridge. All four control pillars are mechanically connected to a master controller in the engine room.

frames being fabricated as in the case of the main generators. Either auxiliary generator may be used if required for charging the two 56-cell banks of batteries which start the engines by motoring the main generators. Starting is accomplished by means of a push button which connects the battery to the generators.

The main propulsion motor, fig. 5, comprises a 500 h.p. D.C. motor direct coupled to the propeller shaft which has a slight rake.

The motor is of the double armature type thereby saving the extra space which would be required by a large single armature motor of the same power and raked at the same angle. The speed of the motor is variable between plus 90 and minus 90 r.p.m. by Ward-Leonard control, and from 90 to 115 r.p.m. by shunt control. Fabricated construction is employed and the magnet frame is split along its horizontal axis and machined inside, the whole being so arranged that the frame can be rotated to give access to the coils in the bottom half of the frame. The two armatures are mounted on a through shaft provided with a forged-on half coupling at the after end for bolting to the propeller shaft. A Michell thrust bearing takes the end weight thrust of the propeller.

SYSTEM OF CONTROL.

Complete control of the tug is effected from either the wheelhouse or the flying bridge, in each of which two control points are provided. The navigation officer is thus able to control the movements of the vessel without the intervention of any human agency in the engine room.

The four control pillars in the wheelhouse, fig. 6, and flying bridge, fig. 7, are interconnected and operate the controls in the engine room through a mechanical system of rods and gearing. A duplicate controller, operated by means of a hand-wheel mounted on the main control board in the engine room is also provided, while a transfer switch transfers the control from the bridge to the engine room, or vice versa. Movement of the transfer switch is only possible however, when all excitation is cut off, the engine room control being only for use in the event of a fault developing in the remote control system.

Fig. 7.—Flying bridge where two control pillars are also installed.

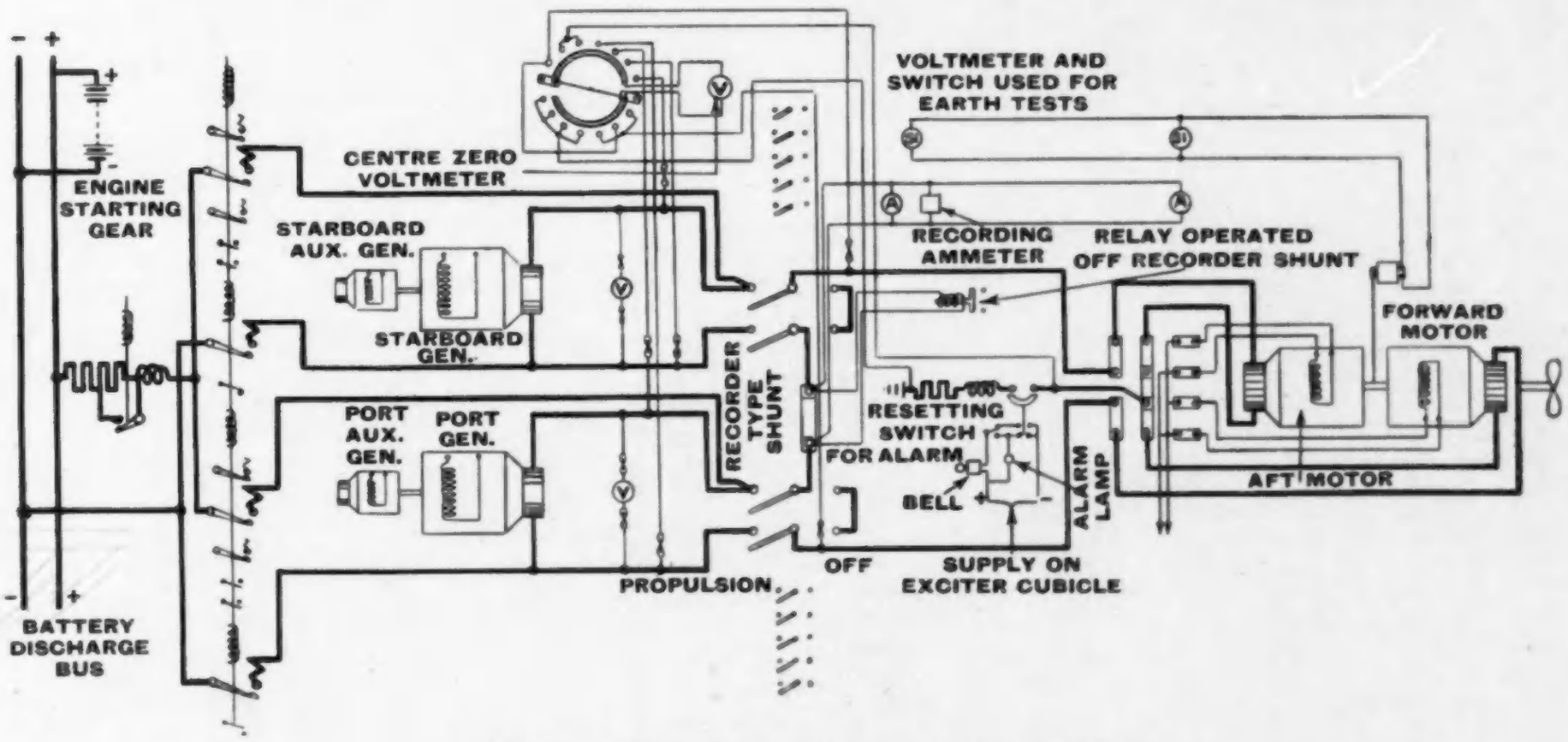


Fig. 8.—Diagram of main propulsion circuits.

As previously indicated, provision is made for starting each engine from either of the two secondary batteries. In normal running the various links and isolating switches are arranged so that

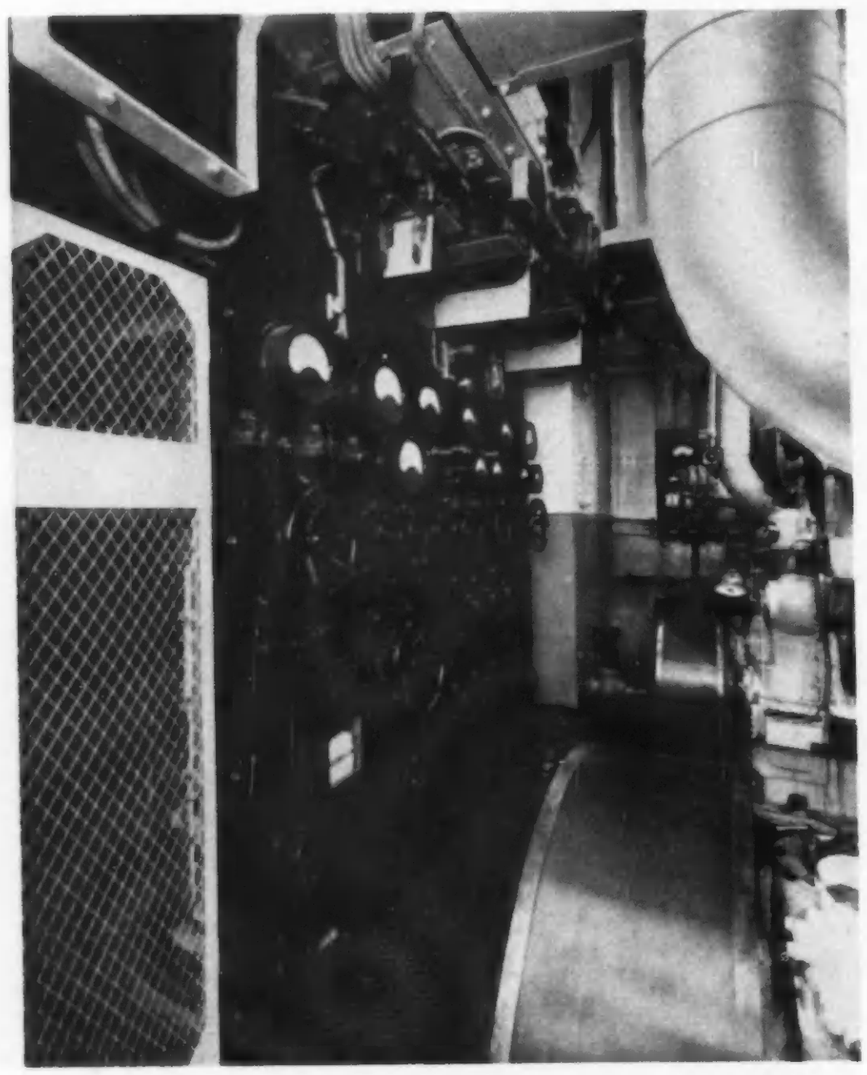


Fig. 9.—G.E.C. main dead-front control board in engine room.

the two main generators and the two halves of the propelling motor form a single series circuit (fig. 8), the mid point between the two motor armatures being earthed through a resistance and circuit breaker.

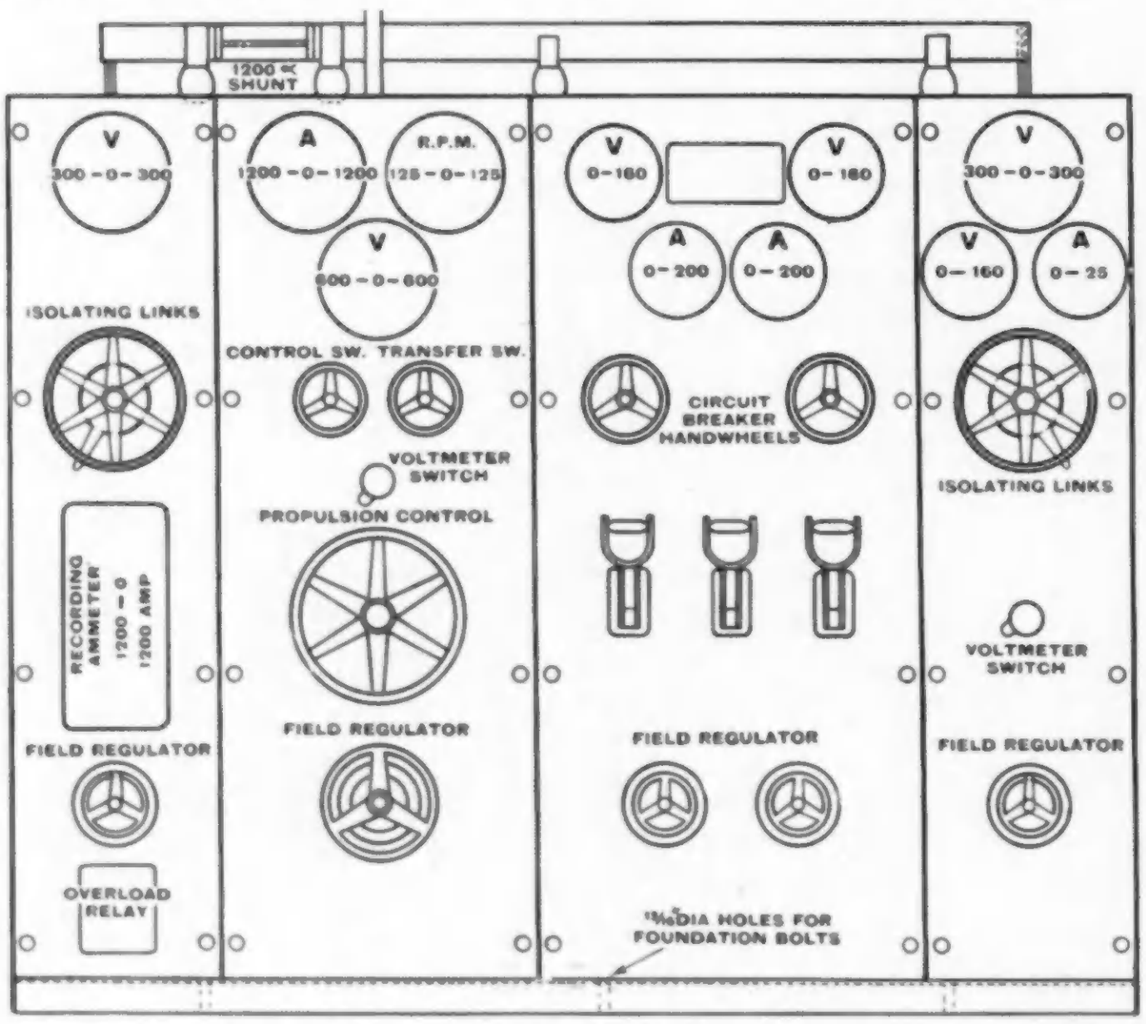


Fig. 10.—Front of main control board showing principal controls.

Propeller speed is varied and reversing accomplished by varying or reversing the separate excitation current of the two generators while a speed adjustment up to 115 r.p.m. is possible by means of a regulator in the propeller motor field circuit.

The propeller motor may also be run at reduced speed from one generator only and the connections are such that the full power output of the engine is obtained. In this way the vessel can cruise economically on reduced speed with one generator shut down. An isolating switch is provided which can cut either generator out of circuit. Further, either half of the propeller motor may be isolated by links mounted on the top of the motor frame, the half remaining in circuit being used for propulsion at reduced speed.

It is of importance to note that the bridge telegraph lever can be thrown over rapidly from full speed ahead to full speed astern without causing the flow of sufficient reverse power to speed up the engines, and without sufficient overpower being demanded after the propeller has been reversed to slow down the engines. This statement applies whether the motor field is at full strength or at the reduced values for the higher propeller speed conditions.

Since possible change of load caused by bad weather conditions might create a temporary overload when running at full speed, a combination of overcurrent and high voltage relays are provided for each generator, so that in the event of a temporary overpower which would be sufficient to slow down a Diesel engine, the relays operate to insert a certain amount of resistance in the generator field, thus reducing the voltage until the overload disappears.

It has been found in practice that with the ship running at full speed ahead, with the engines fully loaded, it is possible to stop the propeller in two seconds, to stop the ship in fourteen seconds and to have the vessel running at full speed astern in thirty-seven seconds. This is believed to be a record for this class of vessel.

CONTROL EQUIPMENT.

The control switchgear is mounted at the back of a "dead front" control board in the engine room (fig. 9), the front of the board carrying the necessary indicating instruments, handwheels and levers for operating the switchgear. All external cables, both main and auxiliary, are led to terminals at the top of the switchboard.

The diagram, fig. 10, shows a front view of the control board. It will be seen that this is divided into four panels, panel No. 1 on the left

controls the port main generator; No. 2, the propulsion motor; No. 3, auxiliary generators; No. 4, on the right the starboard main generator.

On the first panel are mounted the main generator voltmeter, isolator handwheel, fine adjustment field regulator and a recording ammeter and overload relay for the main power circuit. The second panel carries the propulsion circuit ammeter and testing voltmeter, propeller revolution indicator, transfer control switch handwheel, transfer switch handwheel, voltmeter switch, engine room propulsion control wheel and motor field regulator. On the third panel are mounted port and starboard auxiliary generator voltmeters and ammeters, circuit breaker handwheels and tripping knobs, three feeder switch handles and port and starboard auxiliary generator field regulators. The fourth panel carries starboard main generator voltmeter, battery voltmeter and ammeter, starboard main isolator handwheel, voltmeter switch and starboard main generator field regulator.

The 110 volt system used for excitation, battery charging and engine room auxiliaries has three double pole change over switches mounted upon the control board (fig. 10). These switches are for (1) feeding the battery charging circuits from either generator; (2) exciting the propulsion machinery from either generator; (3) general purposes.

Each auxiliary generator is provided with an automatic voltage regulator of the carbon pile type mounted behind the centre panels. The purpose of these regulators is to keep the auxiliary and excitation voltages constant even if the engine speeds vary. A hand regulator is provided for rough voltage adjustments.

PROTECTION.

A latch type contactor is inserted in the main propulsion excitation circuit and is tripped out by an over current relay which functions at heavy overloads. The trip of the latch contactor removes excitation from all machines thus preventing damage and possible short circuit.

A chart recording instrument having three pens is installed, one pen recording the current in the propulsion circuit, while the other two are operated by coils connected to the auxiliary generators and show whether the engines are running or not.

AUXILIARY MACHINERY.

The necessary engine room auxiliaries are installed in such a manner as to give unimpeded access to all parts of the engine room. The equipment on the starboard side includes a switchboard and the bilge and general service pump, fig. 11. The latter is a duplex unit supplied by G. & J. Weir, Ltd. of Cathcart, Glasgow and is driven through a chain transmission by 2 h.p. 900 r.p.m. shunt wound motor. On the port side of the engine room are installed the windlass pump, fig. 12, oil fuel transfer pump and a small air compressor. The duty of the compressor is to charge the two air bottles housed in the funnel which supply compressed air for the whistle.

Fig. 11.—Bilge and general service pump chain-driven by a 2 h.p., 900 r.p.m. G.E.C. motor.

Both the anchor windlass and steering gear are of the electro-hydraulic type, and were supplied by Gemmell & Frow, Ltd. of Hull. The anchor handling unit, which is suitable for ⅞in. stud link chain cable, is in most respects similar to the usual steam windlass with the exception that the cylinders are replaced by two 3-cylinder hydraulic motors which are interconnected through a flanged coupling. The necessary hydraulic pressure for operation is obtained by means of the motor driven pump previously mentioned which delivers oil to the hydraulic cylinders of the windlass. The pumping unit which consists of a three-ram oscillating cylinder pump driven through a flexible coupling by a 10 h.p. 700 r.p.m. compound wound motor, is connected to the windlass by suitable copper piping.

The hydraulic steering gear consists essentially of two horizontally opposed stainless steel rams of 3¼in. diameter bolted to a forged steel rack which engages with a quadrant fixed to the rudder stock. The oil used as a hydraulic medium is supplied

from a 3-cylinder pump driven by a 4½ h.p. 350 r.p.m. motor which is installed on a platform at the after end of the engine room, and is connected with the steering gear aft by piping. Control of the steering gear is effected hydraulically from either of two positions, at the wheelhouse and flying bridge.

SEA TRIALS.

During the last week in August, 1933, exhaustive

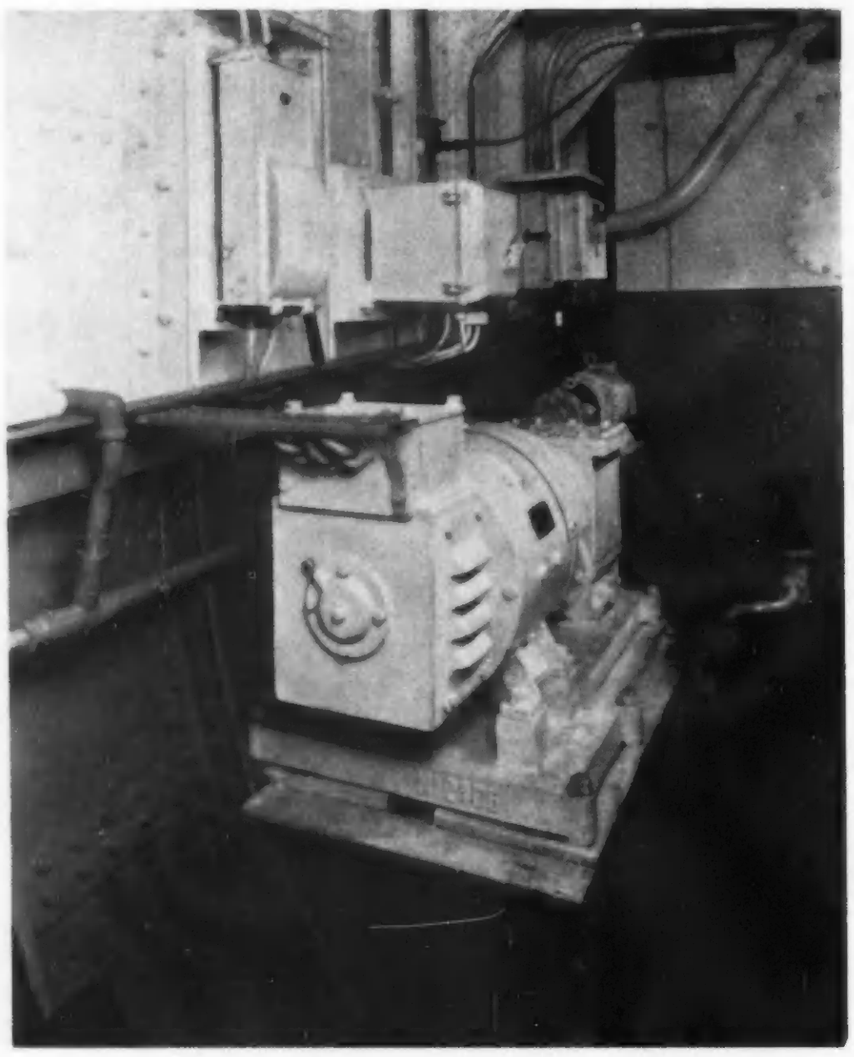


Fig. 12.—Windlass hydraulic pump driven by a 4½ h.p., 350 r.p.m. G.E.C. motor.

trials were carried out at Aberdeen with completely satisfactory results. Particulars of the final sea trials which took place on the 31st August are set out in Tables I and II, from which it will be seen that the trials were of a comprehensive nature and included speed trials on the measured mile, steering and manœuvring trials. The mean speed of 9.6 knots obtained on the measured mile with one engine shut down is particularly worthy of note. The general impressions gained were that the vessel answered promptly and smoothly to her telegraph, while the main engines responded to the variations in load with complete ease. The electro-hydraulic steering gear proved to be thoroughly efficient, the vessel being capable of turning at full speed in under two lengths.

Table I.

Trial Results of the Diesel-Electric Tug *Acklam Cross*, 31st August, 1933.

SPEED ON MEASURED MILE.					
	Tide.	Wind.	Time. min. sec.	Speed. Knots.	Mean Speed. Knots.
Full ahead, both engines, north	Against	With	5 33½	10.795	11.15
Full ahead, both engines, south	With	Against	5 13	11.502	
Full ahead, port engine, north	Against	With	6 28½	9.26	9.60
Full ahead, port engine, south	With	Against	6 2	9.945	
Full ahead, starboard engine, north	Against	With	6 27	9.302	9.58
Full ahead, starboard engine, south	With	Against	6 5	9.863	
Maximum speed attained .. .. 11.50 knots					

MANŒUVRING WITH STEERING GEAR IN POWER.		
	Estimated Dia. of Turning Circle.	Time.
	ft.	min. sec.
At full-speed, hard over to hard over, port to starboard	—	0 6½
At full-speed, hard over to hard over, starboard to port	—	0 8
Full-speed turning circle, port to starboard	160	2 0
Full-speed turning circle, starboard to port	180	2 10
Figure-eight with hand gear	200	4 0
Circle with hand gear, port	200	2 19
Circle with hand gear, starboard	200	2 7

Table II.

Manœuvring without helm.

PROPULSION CONTROL.	
	Seconds.
Both engines—	
Stop to full ahead	24
Stop to full astern	16
Full ahead to stop	14
Full astern to stop	8
Full ahead to full astern	30
Full astern to full ahead	32
One engine—	
Stop to full ahead	21
Stop to full astern	21
Full ahead to stop	16
Full astern to stop	10
Full ahead to full astern	37
Full astern to full ahead	31

These times are for State of Ship and were taken when in commission.
Both engines—Propeller speed 105 r.p.m.; propeller stopped under 2 secs.
One engine—Propeller speed 80 r.p.m.; propeller stopped under 2 secs.

Electrical Equipment for the British Grid.

PART II.—TOWERS, TRANSMISSION LINES AND CABLES.

By H. V. BARTLETT, B.Sc. (Eng.), A.M.I.E.E.,
Overhead Transmission Dept. of The General Electric Co., Ltd.

The accompanying article, which is the second in a series of four describing the equipment which the G.E.C. has supplied to the Central Electricity Board for the Grid, deals with towers, transmission lines and cables. Reference is made in the text to previous articles which have appeared in the G.E.C. Journal bearing on the design of certain auxiliary equipment such as overhead line fittings, etc.

The next article in the series will deal with metering.

IN constructing and erecting the huge network of overhead power transmission lines for the Grid, the G.E.C. and its associated company, Pirelli-General Cable Works, Ltd., have played a prominent part. Of the nine regional areas into which the Grid has been divided the G.E.C. has been responsible for the supply and complete erection of the following lines.

Scheme.	Voltage.	Total length of line.
South East England	132 kV	250 miles
Mid East England	132 kV	325 miles
Central England	132 kV	17 miles
North West England	33 kV	12 miles
South Scotland	33 kV	95 miles

In addition, Pirelli-General Cable Works, Ltd., have manufactured and installed 82 miles of 132 kV single-core, 39 miles of 66 kV single-core, 9 miles of 66 kV three-core and 16 miles of 33 kV three-core oil-filled cable for the Central Electricity Board in London and Newcastle areas.

It will be of interest briefly to touch on the factors governing the design of these towers and cables before passing on to a description of the actual installations.

TOWERS.

Every type of tower used on the grid was subjected to a test before being accepted by the Electricity Commissioners. This work was undertaken by the G.E.C. Research Laboratories at Wembley and a full description of the comprehensive tower testing equipment installed (fig. 2) and the tests made on various types of tower is given in Vol. I, No. 2 of the *G.E.C. Journal*. It may be mentioned here, however, that the design of towers for the grid is such that while any competent bridge designer could evolve a suitable construction from

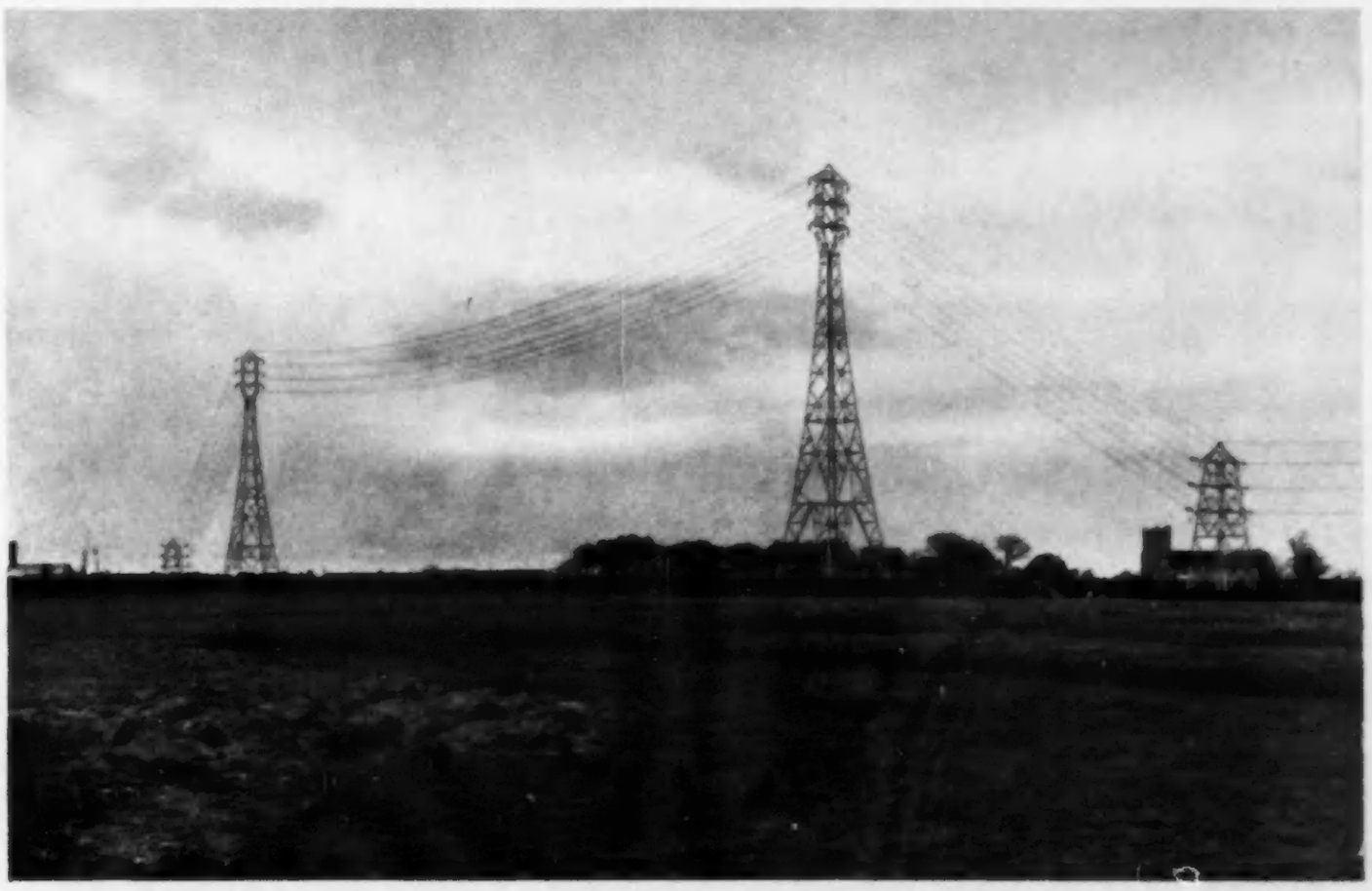


Fig. 1.—River Witham crossing on the Mid-East England scheme. Each tower is 224 ft. high and carries three 33 kV 3-phase circuits, providing a minimum clearance to high water level of 150 ft.; the crossing span is 800 ft.

first principles, there are two great differences which he would have to take into account. The first is that a tower must be capable of supporting torsional loads (which a bridge is never called upon to withstand), and secondly, any waste material in the

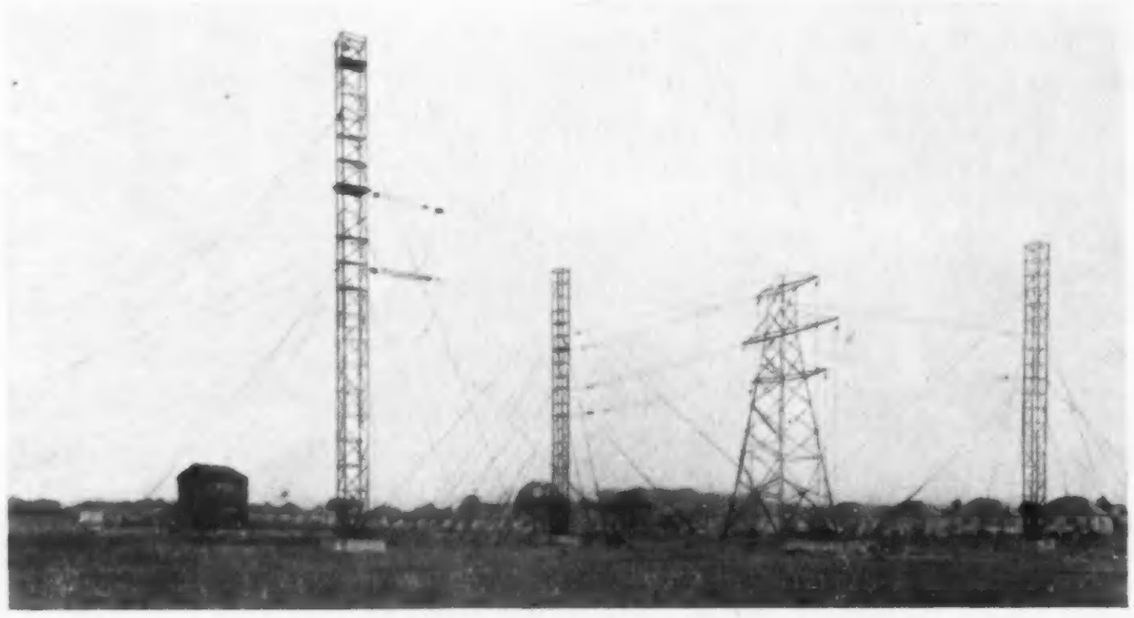


Fig. 2.—Testing plant for towers at the Research Laboratories, Wembley. The view shows a 132 kV double circuit tower undergoing tests.

design must be completely eliminated on the score of expense. Even on a comparatively short line of towers the addition of a few pounds to the weight of a tower has been known to add considerably to the cost of the steelwork of the total line. It is an interesting and significant fact that the factor of safety allowed for towers on the grid is only 2½ and that any tower which failed on test much above this figure was regarded as being uneconomically strong.

Another important factor which enters into the design of towers is the span to be allowed between adjacent towers. It may be stated generally that over flat country short spans are desirable, while over hilly country it is advantageous to use a tower strong enough to support the wires from the tops of the hills over the valleys. Moveover, the height of the towers must be such that the wire is not less than 20 ft. (22 ft. in the case of 132 kV lines) above the ground at the lowest point of its sag. The shorter the span the less will be the sag, so that with short spans light short towers can be used. Long spans necessitate tall heavy towers. With too short a span the line would be expensive owing to the large number of towers required, while with too long a span the cost of the towers could become excessive. The problem therefore resolves itself into finding the mean between these extremes.

There are two types of Grid overhead transmission line :

(*a*) The primary lines carrying large currents at a voltage of 132 kV, and

(*b*) the secondary lines carrying smaller currents at pressures up to 66 kV.

Larger clearances and heavier wires are required by the primary lines, and as the specified loadings are more severe than those for secondary lines, a tower of greater strength is necessary. Steel lattice towers (fig. 3) are therefore used, having a wide base, the towers being spaced about 900 ft. apart. For the secondary lines, towers with narrow bases (fig. 8), spaced about 600 ft. are used.

It is not usually possible to work with one type of tower only ; for any particular scheme three or four designs are usually adopted as standard to suit various degrees of deviation of the line from the straight. Thus, in a typical scheme one design might be adopted as suitable for straight sections of line, and for deviations of 2 or 3 degrees ; another for deviations from 2 or 3 degrees up to 30 degrees, and a third for deviations from 30 degrees to 60 degrees. Towers of special design will probably also be necessary for parts of the line where the standard types are unsuitable. For example, extra long spans may be required in some places for crossing rivers. Every effort, however, should be made to keep down the number of special types, owing to the extra expense involved.

OVERHEAD CABLES, INSULATORS AND FITTINGS.

On all the primary lines of the grid the overhead conductors employed comprise a core of seven strands

Fig. 3.—132 kV double circuit straight line tower as installed in the South East England scheme.

of galvanised steel surrounded by 30 strands of aluminium of the same gauge. This combination has

a strength in the direction of its length nearly twice as great as that of an equivalent aluminium conductor and nearly one and a half times as great as an equivalent hard drawn copper wire.

The method of attaching these cables to the suspension insulators involved the manufacture of special fittings which have been fully described in Vol. II, No. 2 and Vol. III, No. 4 of the *G.E.C. Journal*, while the insulators themselves have been subjected to searching electrical tests. (See *G.E.C. Journal*, Vol. I, No. 4).

SOUTH-EAST ENGLAND SCHEME.

For the South-East England area the G.E.C. supplied about 110 miles of single circuit and 140 miles of double circuit line, interconnecting the sub-stations at Peterborough, Little Barford, Bedford, Luton, Watford, Brimsdown, Barking, Rayleigh, Colchester, Ipswich, Willesden, Uxbridge, Woking and Reading.

All the line towers are of the broad base type and consist of galvanised steel sections bolted together to form the type of structure seen in fig. 3. These towers are designed to carry the vertical and horizontal loads imposed by the line and earth conductors, insulators and fittings, together with a wind load of 8 lbs. per square foot on the whole projected area of the line and earth conductors when coated with a $\frac{1}{2}$" radial coating of ice; also 25 lbs. per sq. ft. on $1\frac{1}{2}$ times the projected area of the members of one face of the tower.

Under these simultaneous working loads the towers have a factor of safety of $2\frac{1}{2}$. They will also withstand, with a factor of safety of $1\frac{1}{2}$, these simultaneous working loads modified by stresses created by broken conductors.

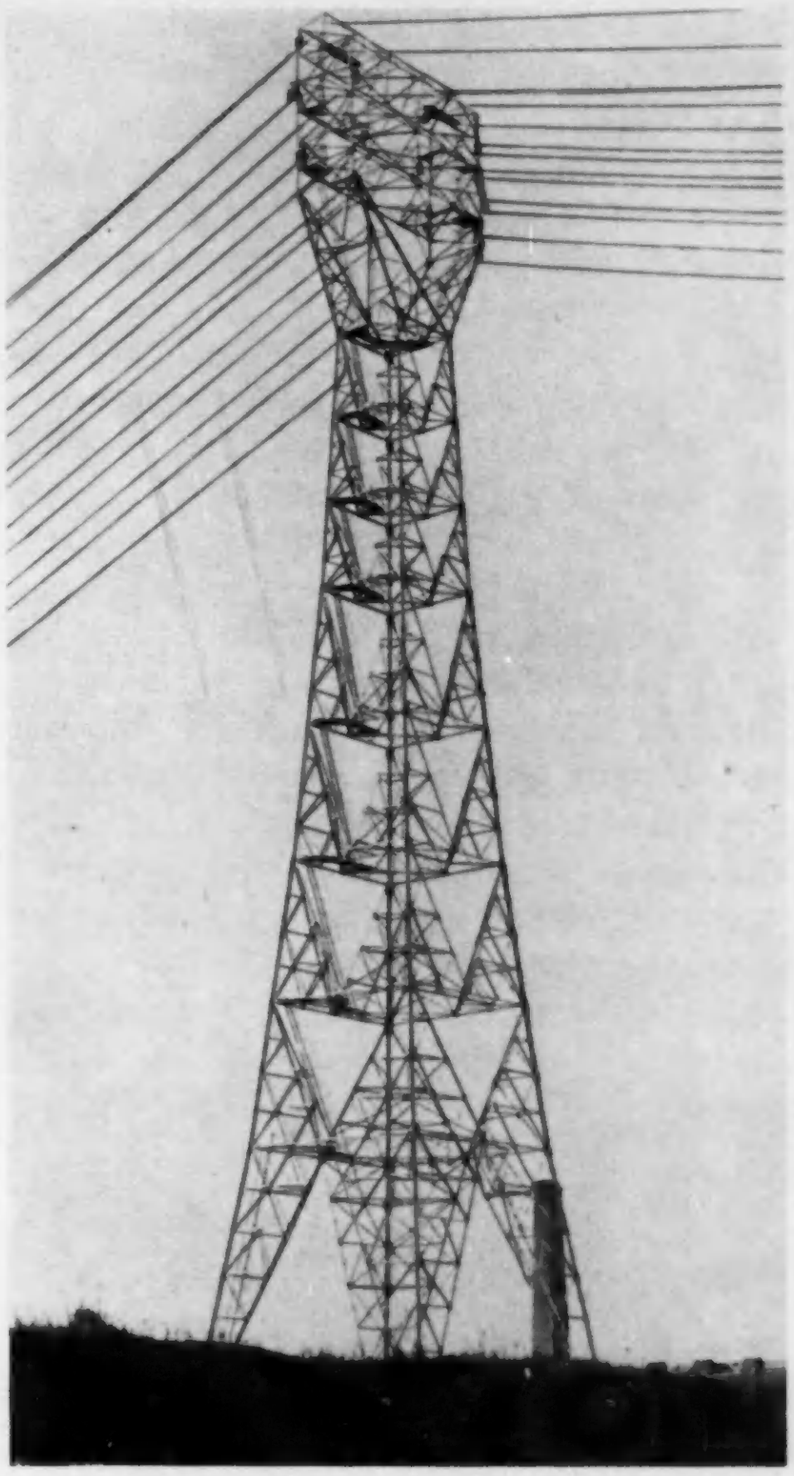


Fig. 5.—362 ft. tower used to cross River Roding in the South East England scheme; tower carries four 66 kV 3-phase circuits.

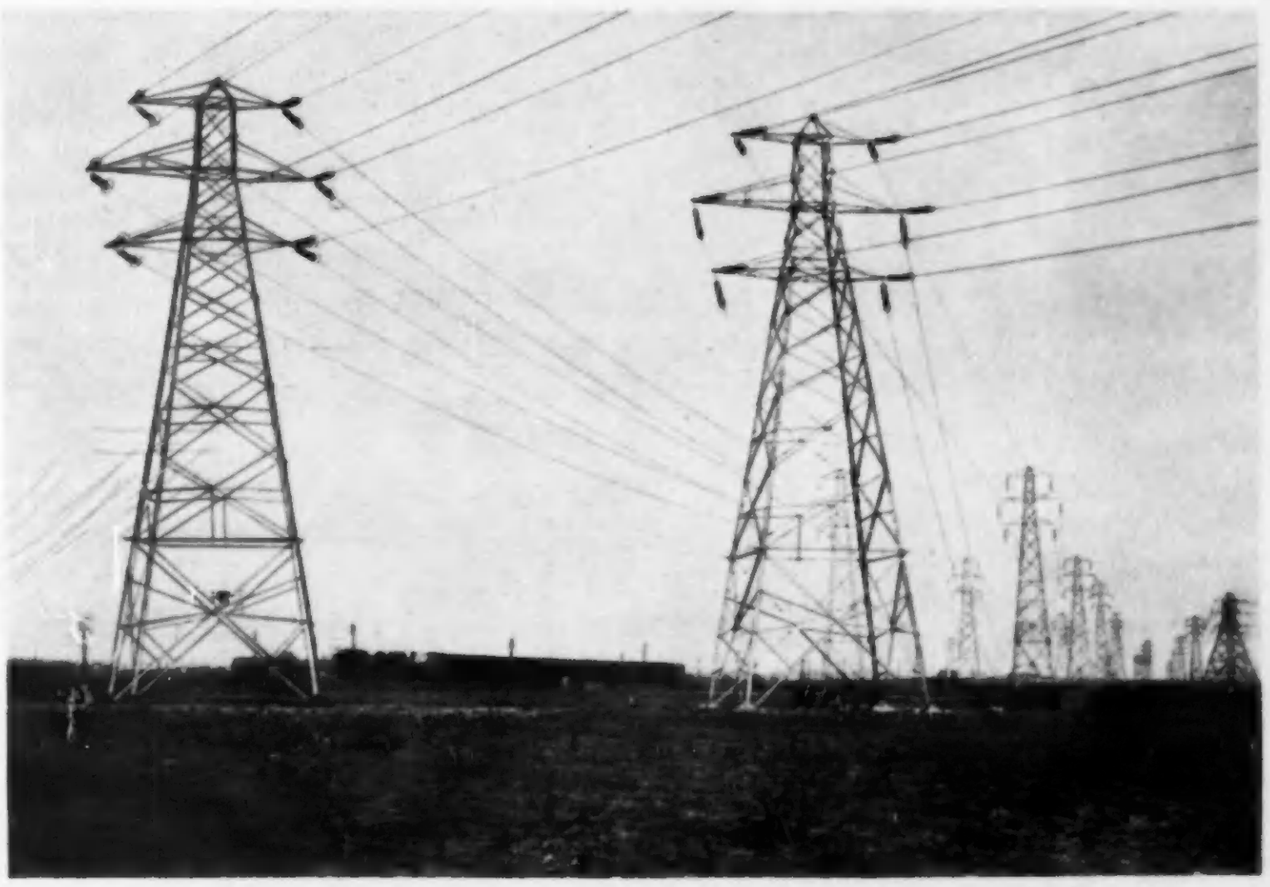


Fig. 4.—132 kV lines in the South East England scheme.

Foundations for the towers are of the "earth," "concrete ball," or "concrete block type," according to the nature of the ground.

It should be mentioned that considerable difficulty was experienced by the Central Electricity Board in obtaining wayleaves for many of the towers in this area owing to the lines extending in the congested areas around London or traversing housing estates. Wayleave difficulties were also encountered in the Thames valley where many residential areas and large private estates exist. In these instances, not only had many alterations to be made to the route of the lines in order to comply with the wishes of the landowners, but also many specially high towers had to be constructed in order to give the lines the required clearance over the housing estates. These special towers vary in

height from 100 to 148 feet and provide a minimum clearance between the conductors and the ground of 40 to 70 feet.

In the Barking area owing to the marshy nature of the ground it was necessary to provide special foundations carried on reinforced concrete piles and shallow foundations.

Both the line and earth conductors are of steel cored aluminium. The line wires have an equivalent copper area of .175 sq. inches, while the over running earth wire has an equivalent copper area of .068 sq. ins. The maximum working tensions are 8,000 lbs. for the line conductors and 6,000 lbs. for the earth conductors. These figures give a conductor factor of safety of just over 2.

The lines are insulated for their full working pressure of 132 kV by means of suspension and tension insulator strings composed of 10" diameter cap and pin units. All insulator strings are provided with a guard ring at the line end, and an arcing horn at the crossarm end as a protection against damage caused by sudden over-voltage, atmospheric dis-

Fig. 6.—250 ft. tower for crossing the River Colne; tower carries one 3-phase circuit.

turbances and the like. At railway crossings, insulator strings are used having an extra high mechanical strength and containing one additional unit in excess of the normal number. This arrangement affords an increased factor of safety from the electrical as well as the mechanical point of view. Apart from this, no other special precautions are needed at railway crossings. In all cases where the lines cross post office telephones and telegraph lines the latter are laid underground.

The amount of sag in still air which the conductors are allowed at a temperature of 22 degs. F. under the assumed maximum working loads is such that the tension in the line conductors shall not exceed 8,000 lbs., while the minimum clearance between the line conductors and the ground in still

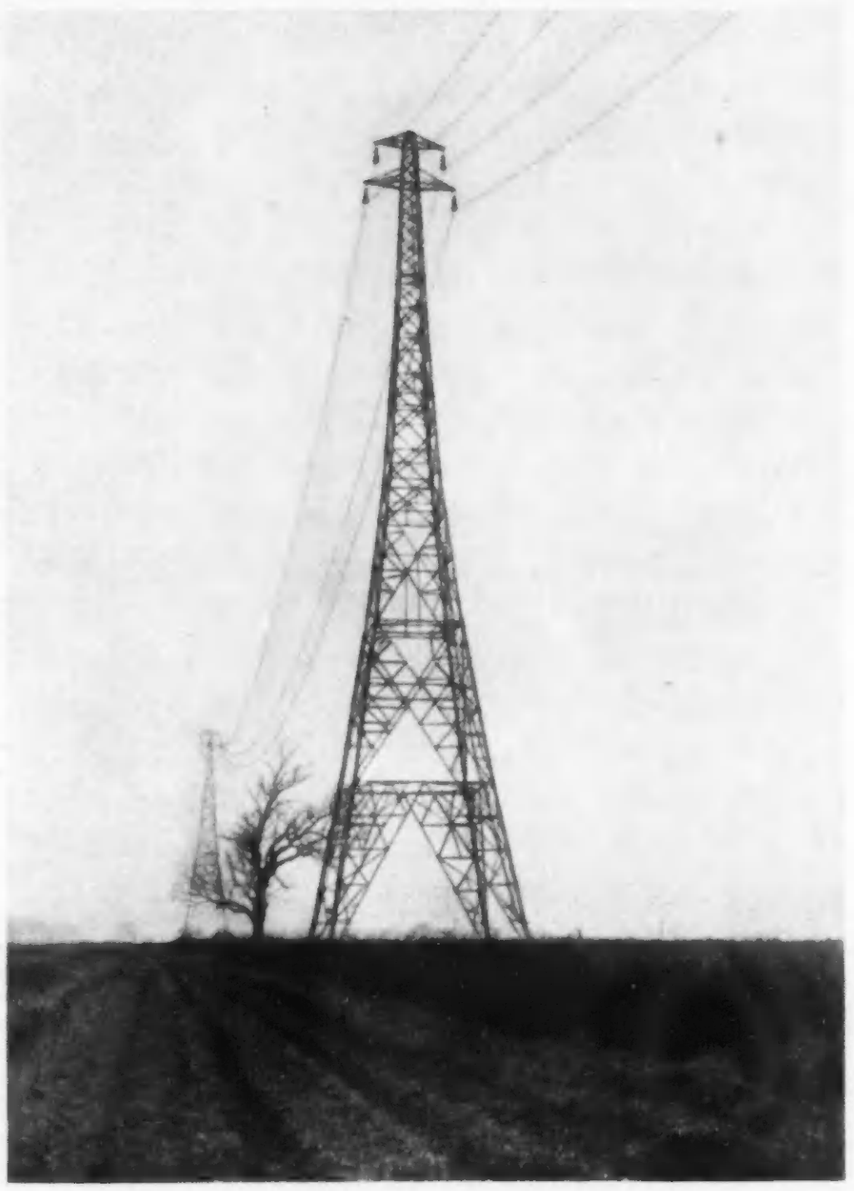


Fig. 7.—River Ouse crossing in the Mid-East England scheme. Each of the two towers is 298 ft. high and carries one 3-phase circuit.

air with a maximum temperature of 122 degs. F. is 22 ft.

The crossing of the river Roding near Barking and the river Colne near Colchester provided two interesting examples of high river crossings. For the river Roding crossing a tower 362 ft. high and 70 ft. square at the base was constructed (fig. 5). This tower carries two double circuits and two earth wires, making 14 conductors in all. The crossing conductors are tensioned off on adjacent anchor towers, the crossing span being 1,820 ft. and the anchor span 1,850 ft. The minimum clearance of the line conductors above high water is 150 ft.

The river Colne crossing tower, fig. 6, is 250 ft. high and carries one 3-phase circuit and one insulated earth wire which can be used as a power conductor in the event of one of the line conductors developing a fault. The crossing span is 1,303 ft. and the minimum clearance at high water 130 ft.

In designing both the river Roding and river Colne crossing towers, a wind load of 11 lbs. per sq. ft. was allowed on the whole projected area of the line and earth conductors when coated with $\frac{1}{2}$"

radial coating of ice, together with a wind load of 1½ times the projected area of the members of one tower face, varying from 25 lbs. per sq. ft. at the ground to 50 lbs. per sq. ft. at the top.

MID-EAST ENGLAND SCHEME.

For the Mid-East England scheme about 275 miles of single circuit line and 50 miles of double circuit line were erected between Peterborough, Lincoln, Grimsby, Hull, Reedness, Ferrybridge, Wakefield, Kirkstall, Bradford, Keighley, Nelson, Thornhill, Sheffield and Rotherham.

These lines are similar in all respects to those supplied for the South East England scheme. Here again all conductor fittings are of G.E.C. manufacture, the tension clamps being of the cone type and the suspension clamps of the trunnion type. A feature of the latter is the diminution of harmful vibration effects, the suspension point of the clamp being level with the centre line of the conductor, thus reducing bending of the latter when a vibration wave passes through the clamp. The slip strength of these clamps is 25 per cent of the ultimate breaking load conductor.

While most of the lines forming the scheme are in country districts, considerable lengths traverse manufacturing areas between big towns. The Central Electricity Board was fortunate in being successful in obtaining wayleaves quickly, and as a consequence it was possible to achieve a high rate of construction, an average of 8 miles of line being erected per week. This involved the installation of foundations, the erection of towers and the stringing of conductors.

In this area the primary line has to cross the river Ouse near Yokefleet, and the river Trent near Alkborough. These crossings necessitated a minimum clearance at high water of 150 and 120 ft. respectively.

The Ouse crossing consists of two galvanised latticed steel suspension towers each 298 ft. high carrying three conductors and an insulated earth wire of the same size which can be used as a power conductor in an emergency. The crossing span is 1,740 ft. and the conductors are tensioned off on anchor towers situated adjacent to the crossing towers.

Each tower was designed for a wind load of 12 lbs. per sq. ft. on the whole projected area of the line and earth conductors when coated with ½" radial coating of ice, together with a wind load of 1½ times the projected area of the members of one tower face varying from 25 lbs. per sq. ft. at the ground to 45 lbs. per sq. ft. at the top.

At the Trent crossing the configuration of the ground is such that only one high suspension tower is required. This is 254 ft. high and carries three line conductors and an insulated earth wire. The tower is situated on the west bank of the river, while on the east bank there is a high cliff which enables the required clearance above high water level to be obtained by the use of an anchor tower of normal height erected on the cliff top. The crossing span is 1,800 ft.

A third river crossing was necessary over the river Witham at Boston, Lincs. (fig. 1). Here there are two suspension towers each 224 ft. high and two anchor towers carrying three 33 kV 3 phase circuits and an earth wire. The crossing span is 800 ft. and the minimum clearance between the conductors at high water level 150 ft.

In designing this tower the corresponding wind loads were taken as 25 lbs. per sq. ft. at the ground to 42 lbs. per sq. ft. at the top.

CENTRAL ENGLAND SCHEME.

Approximately 8 miles of 132 kV 3 phase double circuit line between Hams Hall and Nechells, and 9 miles of single circuit line between Nechells and Ocker Hill were constructed for the Central England scheme. These lines are similar in most respects to those supplied for the South East and Mid East England areas with the exception that painted towers with copper bearing steel tops are employed whereas throughout the remainder of the Grid, galvanised steelwork is used.

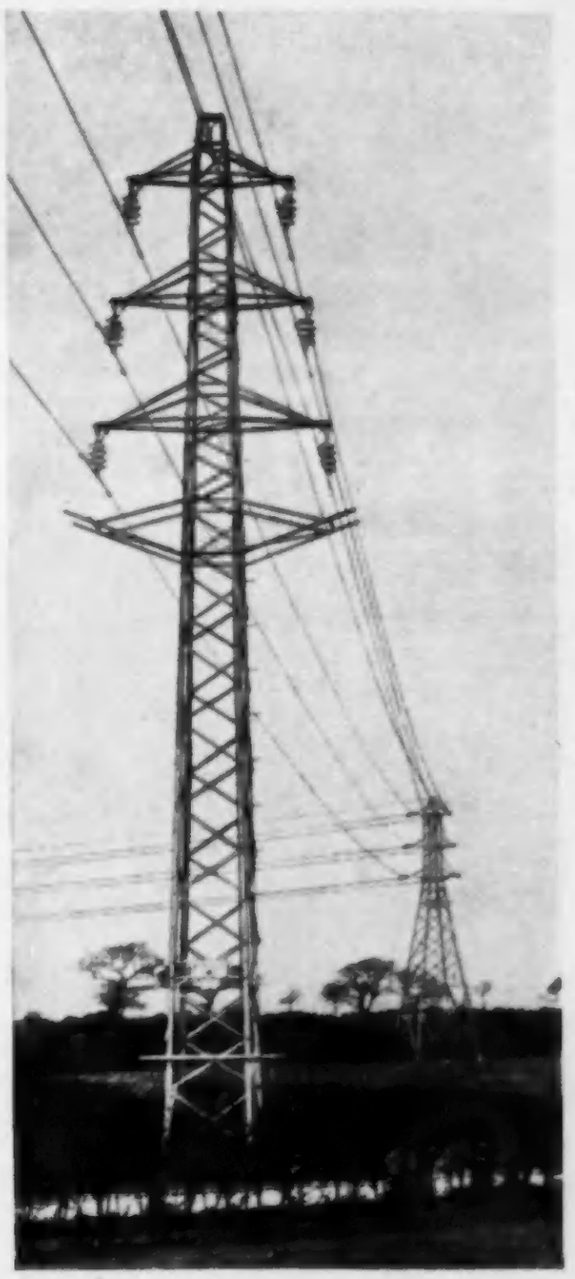


Fig. 8.—33 kV double circuit line between Stockport and Macclesfield in the North West England scheme.

NORTH-WEST ENGLAND SCHEME.

The equipment supplied for the North West England scheme involves part of the North West England secondary line and comprises 12 miles of 33 kV 3-phase double circuit line between Stockport and Macclesfield. The line and earth conductors are steel cored aluminium giving an equivalent copper area of .075 sq. inches.

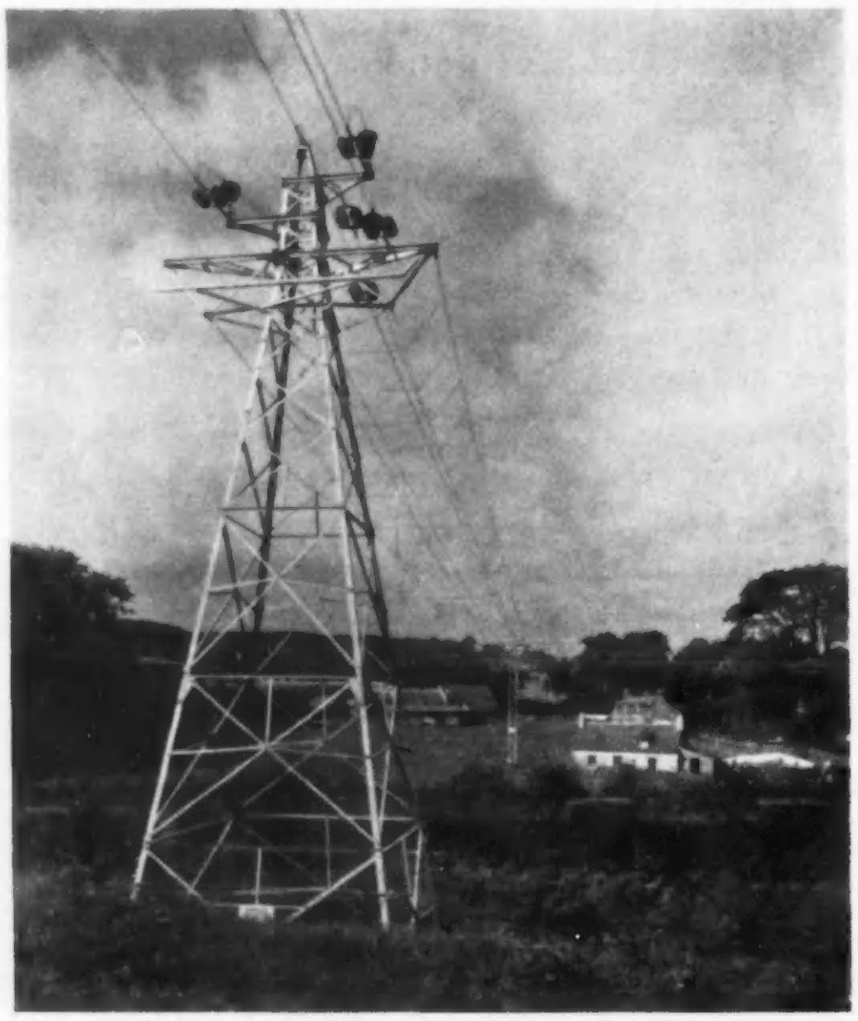


Fig. 9.—South Scotland Scheme: A 33 kV line between Kelso and St. Boswell. The view shows the cradle over a road and telephone wires.

The towers for this line are of galvanised latticed steel, the intermediate and light angle towers being of the self-supporting narrow base type, and the heavy angle and terminal towers of the broad base type. Double strings of insulators are used at each side of all road and rail crossings, while the conductors are erected with a sag in still air such that at a temperature of 22 degs. F. under the assumed maximum loads the tension in the conductors shall not exceed 2,900 lbs., the normal span being 700 ft.

SOUTH SCOTLAND SCHEME.

The 33 kV secondary lines in the South Scotland area form a ring main between Berwick, Duns, Galashiels, Hawick, Coldstream and back to Berwick, a total of about 95 miles of line. Between Galashiels and Hawick the line is 3-phase double circuit, the remainder being single circuit.

Owing to the sparsely populated nature of the district some departure from the Central Electricity Board's usual practice was necessary, and the most economical type of construction consistent with reliability was adopted. Pin insulators have therefore been used on all straight and small angle towers, and duplicate pin insulators on medium angle towers. Large angle, section and terminal towers are equipped with tension insulator strings.

The steel latticed towers employed are of the narrow base type, all straight line towers being self-supporting, while all angle, section, and terminal towers are stayed.

The minimum vertical spacing between adjacent line conductors is 4 ft. and the minimum clearance between the line conductors to the ground 20 ft., the normal span being 450 ft. Single circuit towers are approximately 36 ft. high, and double circuit towers 40 ft. high, the foundations consisting of solid concrete blocks surrounding the base of the towers. A few broad base towers have been employed at special positions.

OIL FILLED CABLE.

Of the total length of oil filled cable mentioned at the beginning of this article 6¼ miles of the 33 kV cable, 27 miles of the single-core 66 kV cable and all the 132 kV cable were installed in the London area, while approximately 12 miles of 66 kV single-core

Fig. 10.—66 kV oil-filled cable being laid across Wandsworth Bridge.

cable and 9 miles of 66 kV three-core cable were installed in the Newcastle area. The remainder of the 33 kV cable was laid in Portsmouth. A full description of the manufacture and installation of oil-filled cable is given in the *G.E.C. Journal*, Vol. I, Nos. 2, 3 and 4.

INSTALLATIONS IN THE LONDON AREA.

The Deptford West Power Station is connected to the C.E.B. outdoor sub-station at Eltham, a

distance of about 6 miles, by means of a double circuit 132 kV oil-filled cable line. The conductor section of the cable is .20 sq. in. and each three phase circuit is capable of carrying 70,000 kVA continuously. An exactly similar cable joins the new generating station at Battersea with the C.E.B. outdoor sub-station at Wimbledon, a distance of approximately $5\frac{1}{2}$ miles.

A further 132 kV oil-filled cable installation connects the C.E.B.'s overhead primary lines between Northfleet and Croydon with the outdoor sub-station adjacent to the Croydon Corporation generating station. In this instance the oil-filled cable forms a single circuit line of approximately $3\frac{1}{2}$ miles.

The 66 kV installations in London connect the Fulham — Hammersmith and Battersea — Fulham power stations by double circuit three phase lines. The single-core cables, both for 66 kV and 132 kV are laid down in delta formation at an average depth of 4′ 6″ and are protected by concrete slabs, the cables being bound together by means of special slips at short intervals to ensure practically continuous contact between the sheaths.

The phase rotation of the cables is changed in every length so that any particular cable returns to its original position at every fourth length. The double circuit lines are laid in the same trench and a distance of 18 inches is allowed between the centres of the circuits.

In the Battersea—Fulham system the 66 kV cable route passes over Wandsworth Bridge (fig. 10) and owing to the fact that the two ends of the steel bridge are free to allow for movement caused by expansion of the steelwork during hot weather, the cables have to be protected from mechanical damage due to strain. This was achieved by building expansion chambers at each end of the bridge to hold loops of slack cable, which are fixed in the expansion chambers to curved steel straps. One end of the strap is fastened to the bridge and the other to the land so that the straps bend to the movement of the bridge and prevent concentration of strain upon any one point of the cable.

INSTALLATIONS IN NEWCASTLE AREA.

In Newcastle, single-core 66 kV oil-filled cable is employed for connecting overhead lines to transformers and switchgear, as for example at Whitby and Malton.

The overhead lines connecting Dunston Power Station with Hebburn and Sunderland are brought through 66 kV oil-filled cable into Dunston and also into Hebburn. The length of cable in the latter instance is 1,365 yards.

An interesting installation of oil-filled cable is in connection with the 66 kV overhead line to Sunderland which is joined up with a three-core 66 kV oil-filled cable running for 2,050 yards into the C.E.B. outdoor station. Both the sub-station at Hebburn and that at Sunderland are connected up to the sub-station at Harton by 66 kV overhead lines, and terminate in 66 kV single-core oil-filled cable. The sub-station at Harton is connected to transformers in the South Shields Corporation power station by two three-core 66 kV oil-filled cables, each of which is 3,525 yards in length. Similarly, the sub-station at Hebburn is connected to the transformers at Carville sub-station by two three-core 66 kV oil-filled cables.

These cables run under the Tyne through a tunnel 447 yards long. The vertical shafts leading to the tunnel are 100 ft. deep and the cables are attached to the sides of the shafts by means of wooden cleats in the same manner as that employed in collieries.

The tunnel itself (fig. 11) is used entirely for cables and owing to the fact that only two sets of racks remain vacant in the tunnel along which cables might be laid, it was necessary to utilize the space to the best possible advantage. For this reason .25 sq. in. three-core oil-filled cables were laid without a joint, each cable weighing approximately fourteen tons.

Fig. 11.—View of the tunnel under the Tyne in which 66 kV oil-filled cable is installed.

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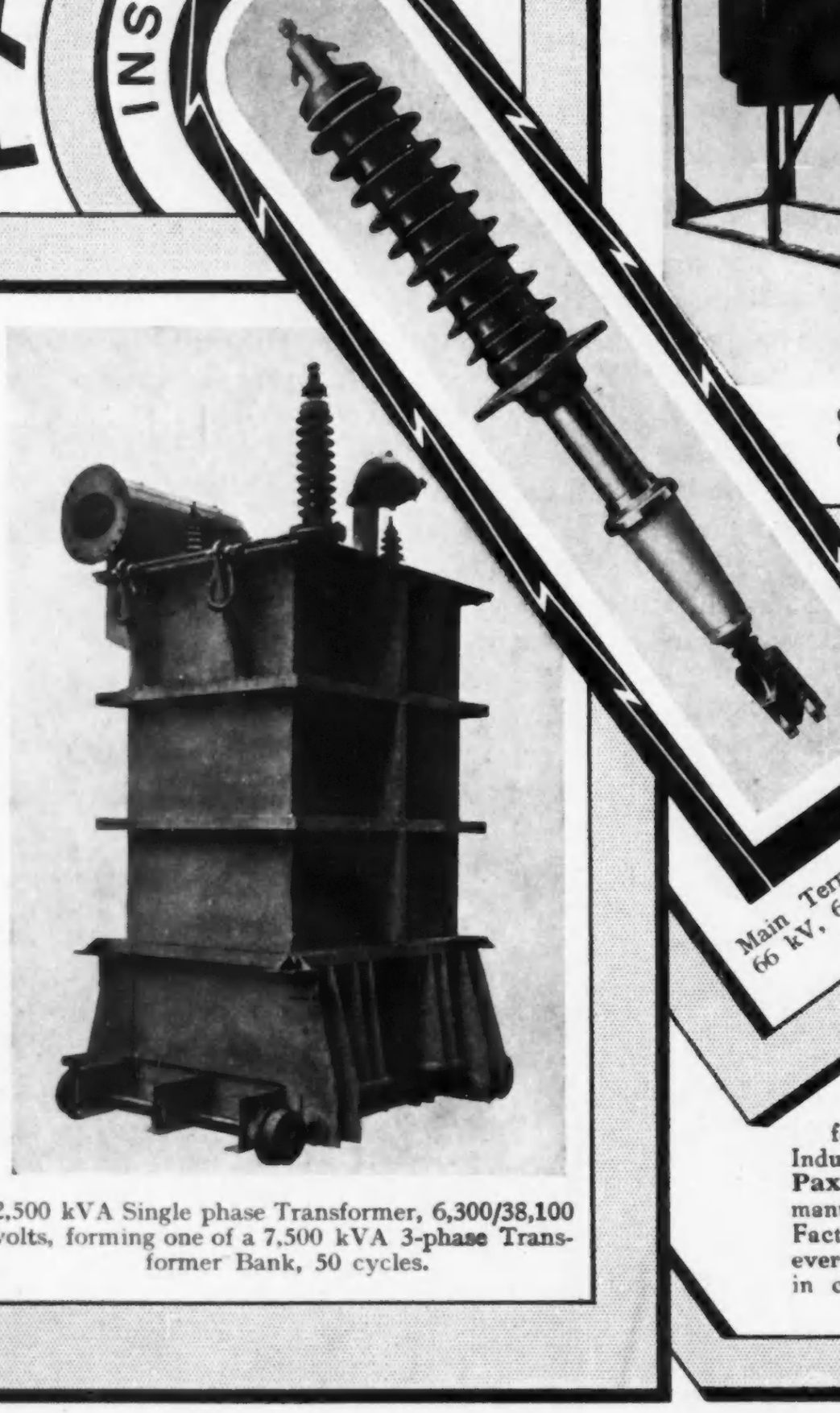

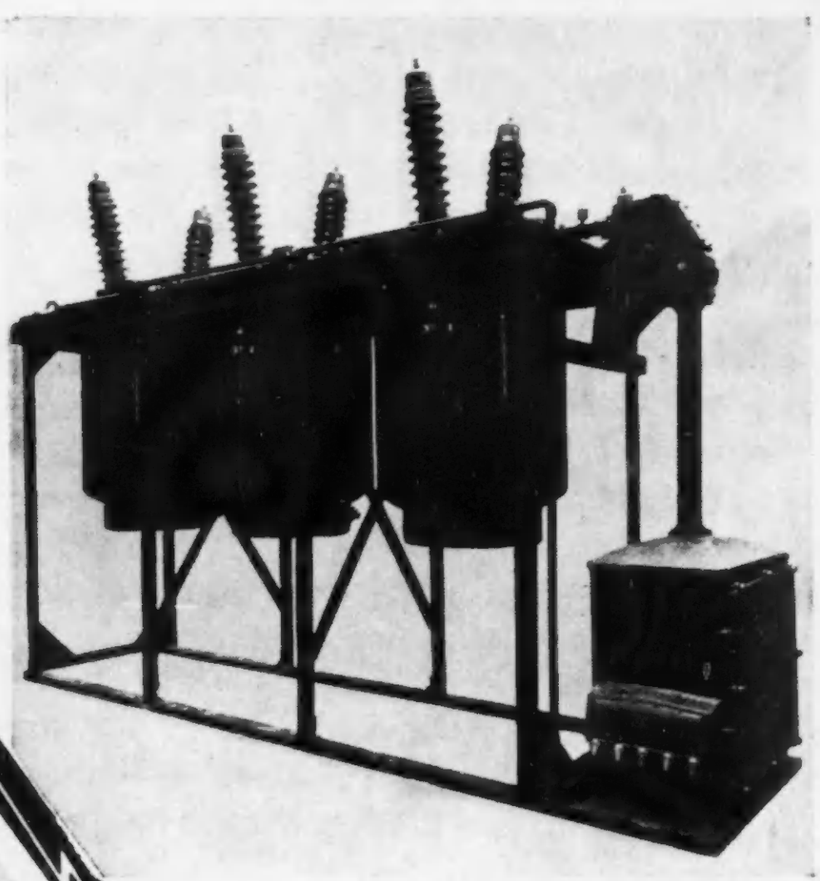

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